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OFFICE OF APPLICATIONS*

by

Morton J. Stoller, Director

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Presented ...

I am pleased to have this opportunity to outline to you the program of the Office of Applications. On my first chart (F62-63) I have listed the functional areas of the Office of Applications.

The first of the program elements that I will discuss is Meteorological Systems. Here our primary concern is with the research, development and application of meteorological satellites and the associated command and data acquisition stations which are needed to establish a meteorological satellite system. These facilities will be used to obtain a better understanding of the weather and how to forecast it. The NASA staff works closely with the Weather Bureau, the weather services of the armed forces, and the international meteorological community in formulating the program.

The second program area indicated on the chart is that of Communications Systems. This segment of the overall program of the Office of Applications includes our activities relating to satellites and ground facilities

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for communication satellite systems. This program area also has its international aspects, as the relations between NASA and its counterpart agencies in other countries, in establishing plans for satellite communications, play an important role in our overall program.

In the Future Applications program area the effort is directed to the identification of other possible applications of spacecraft and the rapid dissemination of information on those technological developments resulting from NASA research and development activities which appear to be useful for general industrial application.

Consider now NASA's meteorological systems activity (chart F62-64). Because an appropriately designed satellite gives a capability to observe the weather from above, it now becomes possible to furnish the meteorologist with map-like pictures of cloud systems over most of the world's surface. The ability to determine just where cloud systems are located, to determine the specific nature of the cloud patterns, and to estimate from successive observations approximately how fast storm systems are moving, and in what manner they are changing, has already been turned into a valuable operational tool by the meteorological services.

We are proceeding as rapidly as possible, in conjunction with the Weather Bureau, to develop a meteorological satellite system which will provide satellite observations for the meteorologist to use in his routine daily operations. Our meteorological systems program objectives reflect these considerations, and are shown on the next chart (F62-2).

In the first phase of the program we are undertaking the development of the equipment and techniques required for the establishment of an operational meteorological satellite system and for the general support of meteorological research. These two end uses may of course lead to somewhat different satellite configurations; for example, the operational systems will require equipment with a very high degree of reliability. Therefore, it is probable that successive operational units will have the same configuration so that the performance can be improved by repetitive use of the same system elements. On the other hand equipment for the meteorological research satellite is necessarily somewhat more experimental in nature and will be flown in various configurations in the course of development.

In the second phase of the program, there are satellite launchings for the continued development of sensors, spacecraft and systems. We expect that these developmental launchings will continue to support the interim operational use of the cloud coverage pictures by the weather services.

The third phase of the program calls for the establishment, with the Weather Bureau, of an operational meteorological satellite system. This system will eventually make it possible for the Weather Bureau and other weather data users to use satellite observations much as they now use ground and balloon observations. Finally, we have an interest in those specialized sounding rocket techniques which are directly adapted to meteorology. Our interest here includes the development of specialized meteorological sensors which can be used in small sounding rockets in regular support of meteorological activities. In the development of this particular phase of our program we are, of course, working closely with the NASA, Weather Bureau and DOD groups doing research in the upper atmosphere and in aeronomy.

The next chart (F62-3) shows the three meteorological satellites with which we are currently concerned. Four TIROS satellites, of the design shown on the left, have already been orbited. The Nimbus, in the center, is the meteorological satellite with much improved capabilities, which we now have under development and construction. The Aeros satellite is shown in a conceptual form on the right, as we have not yet initiated a flight program for this satellite. I will discuss each of these satellites and some of their system elements in somewhat more detail in what follows.

Let me take a moment here to point out on this chart (61-95) the types of sensors used in TIROS. The primary sensor is the TV which, with the wide-angle lens used in all TIROS satellites, covers an area on the ground about 800 to 1000 miles across when looking straight down from the orbital altitude of 450 miles. One set of infrared radiation sensors is incorporated into an instrument called a multichannel scanning radiometer which scans the earth and atmosphere as a result of the rotation and orbital motion of the satellite. The channels of this instrument are so designed that data are obtained corresponding to:

a. The temperature of the uppermost layers of water vapor in the atmosphere (6-6.5 micron band).

b. Night cloud temperatures (8-12 micron band).

c. The total amount of reflected sunshine (0.2-6 micron band).

d. The total amount of heat emitted from the atmosphere (8-30+ micron band).

e. Low resolution cloud coverage (0.55-0.75 micron band).

The second of these channels, which measures the night cloud top temperatures, can be used for rough nighttime cloud cover mapping, as I will show on a later chart. It must be remembered though, that these sensors do not produce a direct TV like picture when collecting the data. Many independent scans, each containing the data on the temperature variation along one line drawn across the surface of the earth, are recorded. Analysis and processing are rather lengthy procedures as yet and additional study and development on high speed data processing methods are required before routine inclusion of such infrared data in daily forecasting can take place. Of the possible applications of the infrared data, only the cloud cover and temperature studies have been investigated. Yet it is entirely possible that infrared radiation data may ultimately turn out to be even more valuable to the meteorologist than the cloud pictures.

TIROS has carried two additional sets of radiometers. Their major difference is the size of the area viewed at any instant. One sees an area about 400 miles on a side. While the other can see the entire area from horizon-to-horizon, it is particularly sensitive to energy in a circle about 1000 miles in diameter centered just below the satellite. Each set contains both a white and a black sensor. The white sensor measures total emitted or outgoing radiation. The black sensor measures this plus that part of the incoming solar energy reflected by the earth, the sea and especially clouds. By subtraction, we can separate the reflected energy and, by again subtracting this from the energy known to be coming from the sun, we can determine how much solar energy was retained to drive the atmosphere and create the weather. It is hoped that meteorologist can in time use these data to develop improved longer range forecasting techniques.

This chart (F62-7) indicates a typical orbital path of a TIROS satellite. TIROS is injected into an inclined orbit. The chart indicates the maximum limits of latitude (about 50° north and south) to which TIROS normally has been providing observations because of the inclination of the orbit. We are now planning on increasing the inclination to about 58°. This should give coverage to a latitude of about 65°.

TIROS has enabled us to make specialized observations of storms and hurricanes. Here is a photograph of Hurricane Betsy which was picked up by TIROS in the western Atlantic Ocean last September (chart F62-9). This satellite photograph of the hurricane corresponds to the hurricane pattern as seen on radar and to a plotting symbol the meteorologists have used for many years. The ability to identify hurricane cloud patterns, to locate them with respect to land masses, and to follow their motions, is one of the major benefits of the meteorological satellite.

The next chart (F62-10) shows in a very abbreviated form the TIROS global cloud analysis for September 11, 1961. We have here a map of the world looking down on the north pole. Each finger-shaped area shows in a very condensed way the cloud information from a sequence of TIROS photographs all taken on this one day. The dark shades represent clouds; the light shading, clear areas as seen by the satellite. For this type of work the photographs are converted to a graphical notation by meteorologists at the data readout stations and the cloud cover maps are sent by wire photo to the U. S. Weather Bureau's National Meteorological Center at Suitland. At that Center they are combined on maps such as this one and further distributed to weather stations all over the world. On the chart there are indicated the major storm and hurricane centers which could be identified in this global analysis. You will notice that we have indicated by the three-legged symbols six distinct tropical storm centers, which were located by the detailed analysis of the data used to make this map.

The next chart (F62-12) indicates one type of data that the meteorologist derives from TIROS infrared observations. The upper chart shows temperature contours; each line represents a condition of constant temperature as observed by the particular infrared sensor in the TIROS satellite, which gives cloud top and earth surface temperatures. The letters W and C are placed to show warm and cold locations respectively. Below these is shown for correlation the cloud cover information from ground observations, for the same period of time at which the infrared data were recorded. The lines here show the altitudes, in thousands of feet, at which the cloud layers were located. Note how the cold areas in the upper chart correspond to the cloud (shaded) areas in the bottom one, while the warm areas are clear. Also, the coldest areas are those where the clouds extend to the highest altitudes. This correspondence shows how we could use such data to observe general cloud coverage at night when we are able to process the data without delay.

Our program calls for 3 additional TIROS launchings at approximately 4 to 6 month intervals so that we can continue to supply cloud cover pictures and infrared data to meteorologists both here and in foreign countries. The cloud pictures can be used for support of regular meteorological operations while both types of data will be available for meteorological research investigations. These TIROS satellite launchings are scheduled to continue until the time when the first Nimbus satellite is expected to be ready to support meteorological operations.

In view of the limited coverage of TIROS, it was apparent at the start of that program that the next step forward would be a satellite whose viewing axis was stabilized in such a manner that the various sensing systems, especially the TV camera, always point toward the earth. Furthermore, to provide full global coverage, we will use a nearly polar orbit. It is helpful also to always have the observations made at the same time of day (at noon for example) when the satellite is on the illuminated side of the earth where the present TV's can work. Fortunately, analysis show it is possible to do this. With the expected accuracy, we should be able to stay reasonably close to this condition for the estimated useful satellite lifetime.

In this chart (F62-15) we show Nimbus in near polar orbit. We have indicated also the fact that because Nimbus is earth stabilized rather than space stabilized, the TV which is mounted on the bottom ring will always be looking at the earth. As a full hemisphere is always illuminated by the sun, with a properly selected initial orbital injection time we can always view the subsatellite point over half an orbital period without difficulty. It is presently planned that this be the northward moving half of the orbit for Nimbus. Notice that to keep the cameras pointed at the earth, and the paddles pointed at the sun, it is necessary to provide for paddle rotation as the satellite travels in its orbit. Also indicated on the chart are the two control and data acquisition station locations.

Now to the Nimbus itself - on this chart (F62-17) we see that the satellite has these large solar cell paddles; there is an upper section which houses the controls; attached to this control housing are the horizon scanners. The horizon scanners are used to activate the controls which maintain the axis of the satellite pointing toward the center of the earth. The control system achieves this by turning flywheels, which are known as inertia wheels, with small electric motors. Should these inertia wheels reach the end of their control range (that is, if their maximum speed is reached) there are gas jets attached to the control section which come into play. These gas jets are used to keep the satellite stabilized while the wheels are slowed down. The conical structure above the control section is simply the upper portion of the command antenna. The straight tubular structure below the control section connects it to the sensor ring; a satellite configuration with such a separation uses the gradient of the earth's gravity field to help realize the desired earth oriented stabilization. The circular tubes are also a part of the antenna. The sensor ring is so constructed that a large number of electronic modules of standardized sizes can be accommodated. Down at the bottom of the ring we see the two units containing the infrared scanners and a bank of 3 TV cameras which are arranged to produce a field of view approximately as shown on the ground below. The three cameras cover overlapping ribbon-like swaths on the ground from pole to pole, as the satellite moves along from orbit to orbit. The infrared scanners will cover a similar stip, actually looking from horizon-to-horizon.

This photograph shows a mock-up of the prototype satellite which is now being assembled (chart F62-14).

In developing Nimbus, we are making an effort to design the spacecraft so that future spacecraft, whether for the purpose of either research and development or for routine operational use, can be assembled rapidly with a minimum of modifications to the basic structure although completely new sensory subsystems may be added. This is illustrated on the next chart (F62-19) where on the left we have shown the basic Nimbus system with its fundamental elements of power supply, controls and sensory package. In the center it is shown as it might be modified, if in the course of the development activity a decision were made to test fly a rainfall radar system. If a special infrared spectrometer, now being developed by the U. S. Weather Bureau to measure the vertical temperature profile of the atmosphere were desired, we might mount this in the center of the sensory package ring, where the TV cameras are now located. The spectrometer package is indicated in outline form in the sketch on the right.

The need for several data acquisition stations for the Nimbus system has already been mentioned. At whatever altitude a satellite orbits, it must be visible at a sufficient height above the horizon for data acquisition to take place. An examination of the geometric conditions that are set by the Nimbus orbital requirements, leads to the conclusion that only by placing a station extremely close to the Pole, could we cover all of the regular daily orbits and so realize global coverage. Alaska is a practical location, which can be used, which is fairly close to the Pole. To complete the coverage, a station diametrically opposite to Alaska at the other side of the Pole would satisfy the simple geometrical condition. Such a location would be impractical in an engineering sense, even if it were available politically, as there are no reasonable cost communication channels available for the transmission of the data to the central data processing location. For this reason, a second station, on the East Coast of the American Continent and as far north as it is practicable to provide the necessary communications is being considered.

The Congress appropriated 48 million dollars to the Weather Bureau in Fiscal Year 1962 for the initiation of a meteorological satellite system, based on the Nimbus program, which is to be ultimately capable of continuous observations. NASA and the Weather Bureau have since that time drawn up an agreement covering the responsibilities of the two agencies and have initiated a project development plan for the Nimbus Operational System.

With the Nimbus development program already underway and the assembly of the prototype moving along, the addition of the

Weather Bureau's funding will result in the procurement of hardware for additional Nimbus satellites of the basic design you have seen here. We then plan to be prepared to launch the Nimbus units about twice as frequently as when the original research effort was scheduled. If all goes well, starting sometime in 1963 we would hope to have at least one working Nimbus in orbit nearly all the time.

The Aeros concept is illustrated in the chart shown here (F62-24). Aeros is conceived as a satellite which will be placed in equatorial orbit at an altitude of 22,300 miles. This will result in its remaining stationary at a given location over the equator from which it can view tropical and temperature latitudes. Aeros will carry, in much the same way as Nimbus, solar cell paddles for power, a controls section and a camera section. The unusual features of the Aeros system are associated with its stationary position with respect to the earth. With this satellite, it is planned to undertake continuous surveillance of the weather systems on the 1/4 to 1/3 of the earth visible below the satellite. Thus we will have a capability for the continuous tracking of a particular storm as it moves over the surface of the earth. The chart indicates the two TV patterns considered for Aeros. One is obtained with a relatively wide angle type of camera which records and transmits pictures of all major cloud systems. The other Aeros camera will be one of relatively high resolution, and very narrow angle of view, compared to the one which covers the total hemisphere. The camera will be directable on command so that any selected area can be brought into the field of view at any time. The areas will be chosen from the wide coverage data.

Why is it that we wish to have another meteorological satellite at such a high altitude, when the Nimbus satellite should give us 100 per cent coverage of the earth's surface? Our calculations indicate that 14 orbits elapse before Nimbus returns and passes in daylight over about the same area of the earth as it did in its first orbit. Roughly, the same area is covered, but in a pass in the opposite direction and at night, every seven orbits. This means that about every 12 hours we get another observation of a given spot on the earth's surface, but are limited on alternate passages to the use of the infrared techniques, until we can develop a TV camera that can see clouds at night.

The importance of more frequent or continuous observations is illustrated in the next chart (F62-25). Here we have shown the typical lifetime of certain common weather systems: tornadoes, thunderstorm cells, hurricanes and major cyclonic storms. The chart shows the general relation which exists between the lifetime of these systems and their typical size. We have also show the time between observations (about 12 hours) which will result if one Nimbus satellite is up and if two Nimbus satellites are in orbit. In both cases we are assuming we are using the night-time as well as the daytime observations. With one Nimbus in orbit, about half a day passes before we again see the same area. This will be a reasonably satisfactory time for the observation of such systems as cyclonic storms and hurricanes whose normal life is considerably greater than 12 hours. But, if we attempt to observe thunderstorm cells or tornadoes, systems whose life is appreciably less than 12 hours and often less than 6 hours, they will usually form, move and die out without ever being detected. It is for this reason that the Aeros satellite, with its capability for focusing on small short-lived storm systems and tracking them continuously, is considered to be an integral component of the eventual operational system.

Another aspect of the meteorological research and development program is reflected in the effort devoted to the continuous improvement of meteorological sensors, electronic and mechanical components and systems configurations. These activities are coordinated with similar program studies arising in other areas of interest in order to so direct the work that more than one flight development program can benefit. New types of infrared sensors for the measurement of quantities of meteorological interest, and new data storage devices for use in the satellites are typical of the items covered in the advanced research program.

To complete this review of the meteorological systems program I wish to mention briefly the meteorological observations made with sounding rockets, which supplement standard ground station observations, balloon sounding and the satellite data. In particular, we have been working with a method known as "grenade sounding." In these tests, a series of small explosions is produced at a number of altitudes by ejecting grenades from a sounding rocket. The time of arrival of the sound wave from each explosion is measured at a group of microphone stations on the ground. The location of the grenade at the time of firing is also determined with radar and/or optical instruments. The use of appropriate data reduction procedures then enables us to determine both the winds and the temperature in the upper atmosphere up to the altitudes at which the last grenade was exploded. The chart (F62-26) shows the general arrangement for such a sounding. The facilities include a launcher for the sounding rocket, the "DOVAP" system, which tracks the rocket so as to locate it in space at the instant of an explosion, and microphones, represented by the numbered locations in the vicinity of the DOVAP stations. The photograph shows a typical grenade head for the sounding rocket.

On the next chart (F62-27) are two typical results which have been extracted from data for many sounding rocket flights at Fort Churchill, Canada, at a latitude of about 59° north. Note that the winds change appreciably from the winter season to the summer season. This phenomena could not have been determined without the rocket soundings because only the lower altitude conditions can be measured with conventional balloon soundings. Furthermore, we know of no satisfactory techniques for observing these altitudes from satellites. The transition point at which the wind direction shifts is where the balloons start to reach their limit and the data shown from 100,000 feet on up have all been acquired with sounding rockets.

Let me turn now to a review of our program in communications systems (chart F62-65). It has been obvious for sometime that the communications satellite has a tremendous potential for improving our ability to communicate with the other nations of the world and for making this capability available to all. The improvements possible in channel capacity and in cost per channel may lead to the substitution of satellites for the undersea cables on which we now depend for transoceanic telephone communications. Economic studies which have already been undertaken indicate that with the development of the communications satellite it will be possible to provide services closely comparable in performance to those of the underseas cables, at lower costs per channel than we now experience with the undersea cables, and that we will be able to expand the system to a capacity well beyond that which would be economic with cables alone. Related studies on the number of channels that are predicted as being required for overseas communications indicate that in a decade or so, the addition of communication satellites will be almost a necessity, if we are to keep up with the demands of service to other countries.

While the usefulness of the communications satellite and its importance in world-wide communications is clear to all, it is not immediately apparent which of the technical approaches to the problem will turn out to be the most rewarding in arriving at the design of the operational systems of the future. Accordingly, NASA is endeavoring to determine, as rapidly as possible, which of the various system designs which have been proposed should be used in the establishment of operational communications satellite systems.

On this chart (F62-29) I have indicated the objectives of our communications systems program. The first of these is the demonstration of the feasibility of both the active and passive communications satellite techniques. Our second objective is to move as rapidly as possible toward the establishment of the operational system.

The third of the objectives is to support the operational communications satellite system through continued research, development, and flight tests.

On the next chart (F62-30) there are indicated the three major communications satellite systems which offer sufficient promise to warrant continued detailed investigation. The first of these is the system using low or intermediate altitude passive reflectors. The second uses low or intermediate altitude active repeaters, and the third depends on high altitude, synchronous, active repeaters. Perhaps at this point I should remind you that the passive, or reflector satellite does not carry with it any power supply receiver, or transmitter. It is used simply to reflect the radio energy from one terminal of the communications satellite system to another. Active repeaters draw their name from the fact that they carry receivers, transmitters and sufficient power supply, so that the message to be transmitted is received, amplified, and retransmitted to the far terminal. By low or intermediate altitudes, we mean from several thousand miles to as much as twelve thousand or so miles. By high altitude, synchronous, is meant the 22,300 mile orbital condition already mentioned in connection with Aeros, in which the satellite apparently remains fixed over a point on the earth's equator.

The next chart (F62-31) shows pictorially the elements of a low altitude active communications satellite system. It is charcterized by terminal stations with large antennas and by a number of satellites orbiting at low altitude. The reason for the large number of satellites indicated on the chart is that the time that any one of these satellites is visible to both of the terminal stations is limited, when the satellites are in orbit at low altitude. Consequently, to get continuity of transmission between the two terminals, a number of satellites must be put into orbit, and these must be so distributed in space that at all times, at least one can be used as a communication link between the terminal station.

A realistic appraisal indicates that unless fairly complex provisions are included for controlling the position of the individual satellite in its orbit, it must be expected that the satellites will come after a period of time to an essentially random set of spacing.

An example of the results of calculations on the number of satellites that are required for the maintenance of communications at several orbital altitudes is given in the next curve (chart F62-32). Here we see how many satellites are needed for substantially continuous service between ground terminals located some 3,000 miles apart. Note that if we were to orbit the satellites at an altitude of only 1,000 miles that as many as 400 randomly distributed satellites would be required. If we plan to use the 5,000 mile altitude range, then we can immediately cut the number of satellites required to 40. Suppose we plan on using the 22,300 mile altitude, which is about as high as we would wish to go for reasons I will mention in a moment: 19 satellites are shown to be required by the analysis. In actuality, if we were to orbit the satellites at 22,300 miles, and it were possible to exert effective precision control of their orbital velocity, we would not use randomly distributed satellites at all but would establish what is known as a synchronous satellite system.

The synchronous satellite system is illustrated on this chart (F62-33). It is of great interest in communications work, because at the 22,300 mile altitude, the spacecraft will remain fixed over a point on the equator and it is only necessary to have three units up to provide for basic world wide coverage. As it is by no means certain how long it will take to arrive at a control configuration of adequate reliability and precision, research on the synchronous system is being conducted parallel with that on low altitude systems. The DOD's project Advent is directed to the development of a military communications satellite system of the synchronous orbit type.

I have already mentioned that a communications system with the satellites at low altitude will require a number of satellites in orbit simultaneously. In addition spacecraft and launching costs are likely to accumulate rapidly with such a system. We are studying techniques whereby we can launch a number of satellites into orbit from a single booster vehicle and have initiated work in this area which we expect will lead to a flight experiment within the next few years. The multi-launch concept which is illustrated on this chart (F62-34) calls for the insertion of a number of satellites into orbit from a single booster; the example shows three. The booster leaves the launching pad and goes into an elliptical orbit. This puts the spacecraft, which is carried by the launch vehicle and which has within it the three communications satellites, also into the elliptical orbit. When the spacecraft carrying the three communication satellites reaches its apogee, the first of the communication satellites is ejected and an additional rocket propulsion unit attached to the satellite is fired. This satellite is therefore put into a circular orbit about the earth because of the additional velocity that has been given to it. At apogee, each of the next two times around the spacecraft unit again ejects a communications satellite which is also given sufficient additional velocity by an appropriate rocket for it to maintain a circular orbit. So it has, in the course of three of its elliptical orbits, put three communications satellites into circular orbit. A procedure for multiple satellite injection seems to be a necessity, if we are to proceed with operational low altitude communication satellite systems.

Having discussed some of the reasons for the different orbital configurations proposed for communications satellites, let me now review the satellite themselves. Basically, the simplest of all the communication satellite techniques is the passive reflector - the radio mirror in the sky. At the present time NASA is investigating four of these configurations, as they appear to have the most promise for immediate application. These four are shown on this chart (F62-35). The first is the simplereflecting sphere. This, of course, has been tried already, in Project Echo. As a follow-on to the simple sphere with a continuous surface, there are two varieties of surface structure which promise better overall performance so far as the passive reflector communications system is concerned. One of these is a sphere which has been lightened by etching holes in the metallic foil which constitutes the reflecting surface. This reduces the weight and makes it possible to orbit a larger satellite, which will have correspondingly improved performance, with the same launch vehicle. An alternative is to make the sphere of an appropriately sized wire mesh. As we wish to make the sphere very much larger insofar as its reflection characteristics are concerned, we are also looking into the possibilities of effectively accomplishing this without actually orbiting the whole sphere. In normal circumstances only the bottom face of the sphere, the portion facing the earth, is actually used in reflecting the signal from one station to another. For this reason it seems rather unnecessary to orbit the upper portion, which serves no purpose in the communication satellite system. The problem then become one of erecting, and then stabilizing, the spherical segment that is placed in orbit to hold the reflecting face towards the earth. Studies of the spherical segment reflector and of the stabilizer will therefore be carried on together, because without the second, the first is of little use.

NASA's passive satellite program includes several flight tests. The properties of the sphere as a communications reflector are being evaluated in these flight tests. The first of these tests was the Echo I project. Most of you have probably seen Echo moving across the sky and may be interested to learn that we are continuing to measure its reflection characteristics to see if any more significant changes in its shape or surface conditions occur. To refresh your memory, the left side of the next chart (F62-36) shows that Echo was 100 feet in diameter, weighed 135 pounds and was constructed of mylar plastic film 5 ten thousandths of an inch in thickness. This is approximately 500 millionths of an inch in thickness, about one quarter of the thickness of a human hair. The mylar film was made reflective to radio waves by evaporating an aluminum film on to the plastic in a vacuum chamber. After the Echo sphere had been in orbit for some time it exhibited a certain amount of wrinkling and there were small changes in its shape which are associated with the loss of the original volume of inflation gas. As the sphere wrinkled, it became less acceptable as a communications reflector, as a smooth surface is the best reflector. Accordingly, we have now built a new version, Echo II, which is shown on the right, a sphere which will maintain a fairly smooth surface characteristic. In designing this reflector, we took advantage of the availability of a large booster vehicle to make the sphere larger. It will now be 135 feet in diameter, and will weigh about 500 pounds. In this case the sphere is made of a laminate, a combination of two layers of aluminum foil, and one of mylar, as is indicated on the chart. The total thickness will be 750 millionths of an inch. This is 50 percent thicker than Echo I, but is appreciably stiffer because of the presence of the two layers of aluminum foil. When this sphere is inflated (F62-37) and somewhat over pressured, it takes on a permanent set, and does not tend to resume its earlier wrinkled condition when the gas pressure drops. The major objective of the Echo II project is to show that a rigidized structure of this type is a practical one as a passive reflector.

Let us look at the specific versions in NASA's active communications systems program.

The Relay developmental spacecraft is shown in this chart (F62-41). This is the test model which has been built by the Radio Corporation of America, the prime contractor for Relay. An artist's conception of the Relay satellite in orbit is shown on this chart (F62-42). The shaded area which you see here indicates the antenna patterns of the Relay satellite. Notice that it is doughnut like in form so that even though Relay spins on its long axis, some of its energy will be radiated toward the earth. A magnetic attitude coil similar to that used in TIROS will be used periodically to adjust the orientation of this axis to a favorable position with respect to the ground stations cooperating in the Relay experiment.

NASA is cooperating with the American Telephone and Telegraph Company on the Telstar project (F62-44). This project was initiated by AT&T and also has as its objective the investigation, in orbital flight, of the technical and operational problems of transmission of wide band communications by an active communications satellite. The Telstar satellite which is being built by the Bell Telephone Laboratories is of a different configuration, and has a number of technical details which differ from those of the Relay satellite. The division of responsibilities for the work that is being carried on by NASA and AT&T for Telstar is indicated on this chart (F62-45). NASA is responsible for the establishment of the environmental test specifications of the spacecraft, will procure the launch vehicle, launch the spacecraft, and will undertake the orbital data acquisition necessary for the operation of the ground tracking stations.

AT&T is responsible for both spacecraft and ground station development. Both NASA and AT&T will undertake data analysis and processing so as to support the development of future spacecraft and ground systems. The data resulting from the project will be exchanged without any constraints between the two organizations and will also be available to others in this country and in the international community.

Both Relay and Telstar have already given rise to a great deal of international interest and NASA has entered into agreements for experimental work with the Relay satellite with Great Britain, France, Germany, Italy, and Brazil. Discussions with other countries have taken place, and it is expected that additional agreements will result.

The third active satellite project in our present program is Syncom, which is being built by the Hughes Aircraft Company (chart F62-67) -- this is NASA's initial effort directed to the development of the synchronous satellite. Its objectives are to provide experience in using communications satellites in a 24-hour orbit at the earliest possible time; to develop the capability of launching satellites into the 24-hour orbit using existing launch vehicles plus additional "apogee kick" rockets and to test the life of communications satellites components at the 24-hour orbit altitude. The spacecraft itself is shown in this artist's conception chart (F62-59). The interesting part here is the addition to the spacecraft of the apogee rocket motor, the control jets for orientation and positioning and solar sensors. The traveling wave tube is used in the transmitter of all three active satellites because of its excellent performance characteristics.

It is particularly useful when a wide range of frequencies is to be amplified as is the case here. Now, with the help of the charts which follow I will try to outline for you the way in which it is intended to get the Syncom satellite into a satisfactory synchronous stationary orbit at an altitude of 22,300 miles. (Chart F62-50). The initial injection of the satellite will be from the Cape into a very highly elliptic inclined orbit with an apogee of 22,300 miles. As a result, at apogee it will be at the desired altitude for synchronous rotation with the earth. However, it will not have had enough energy imparted to it to stay at that point, and the internal apogee rocket must be fired to add the energy required.

When the satellite is separated from the lower stages of the Delta launch vehicle, it is spun about its axis and so it is rotating much as a gyroscope would rotate, as it comes up to altitude.

When the apogee rocket is fired, the satellite will be injected into a circular orbit. At this time the attitude control jet in the end of the satellite can be actuated by ground control to provide a force to turn the satellite. The result of this operation is indicated in this view. The satellite then appears to be rotating on its axis like a wheel as it moves in its orbit.

On the next chart (F62-51) we see the satellite in its orbit above the earth. It is more than likely that the satellite's speed in orbit will be somewhat too fast or too slow for an exact match with the earth's rotation and it will tend to progress or retrogress around the earth. A result of the inclination of the orbit is to make the point below the satellite trace a path resembling a series of connected figure eights as shown here. An additional element of ground control is then available in the positioning gas jet in the side of the satellite. This force will slow the satellite down or speed it up in its orbit depending upon the direction in which the jet is pointed when it is operated. This controllable jet can be used to reposition the satellite to the location where we would like to have it for communications experiments.

The next chart indicates the final position of the Syncom satellite (chart F62-52). It will still be rotating about its axis and will be moving in a figure eight pattern about 30° above and below the equator.

The antenna pattern of Syncom is indicated on the right hand portion of the chart. It resembles that of Relay in that it is uniform around the satellite axis and so the rotation of the satellite will not affect its performance.

NASA and the Department of Defense both have responsibilities in the Syncom project. These are shown on the next chart (F62-53). NASA is responsible for the spacecraft development and launching, and for the orbital data acquisition and processing. The Department of Defense is responsible for the development of transportable ground stations for use with Syncom. Much experience has already been accumulated within the Department of Defense on the Advent ground station design for this type of service. It was possible to take advantage of this experience by arranging with the Department of Defense for a supporting effort for the Syncom project. Both NASA and the DOD will undertake data analysis and processing to support further research and development on both the spacecraft and the ground systems for synchronous satellites.

We are now formulating and firming up the advanced research and development for the communication systems which will follow the first phase of the passive and active satellite project developments I have just discussed. The chart (F62-54) lists several major areas in the general category of advanced research and development. Studies of ground systems components, satellite systems components, attitude stabilization, and an evaluation of the effects of the orbital environmental radiation are underway. In considering ground systems components, detector units, receiver circuits, transmitters, modulators and antennas are of primary concern. Insofar as the satellite systems are concerned, it is obvious that the testing of particular receiving and transmitting systems, and power supply arrangements will be required. Studies of the configurations needed for redundancies in space borne systems in order to develop the reliability required for long operational life will have to be continued.

Attitude stabilization for passive satellites is vitally important if we are to get away from the sphere as the only effective reflective satellite structure. Both the synchronous satellite and the low altitude satellite will also show a great deal of performance improvement if we can develop a stabilization system which will eliminate the need for satellite spin and which will hold the satellite in a fixed attitude relative to the earth. We could then use an antenna on the satellite which will focus in the preferred direction to improve the power transfer both from the earth to the satellite and from the satellite back to the ground. Accordingly, from the very first we are trying to concentrate on attitude stabilization system designs which have inherent simplicity and reliability.

Low altitude satellites will generally spend a fair percentage of their life passing through the Van Allen Radiation Belts. For this reason, we already have planned an investigation of the environmental radiation of these belts with both the Relay and Telstar satellites. Both of these will carry radiation monitoring instrumentation and radiation damage detectors. These radiation investigations will continue until we have sufficient engineering experience and an adequate statistical basis to determine just what protection the various electronic and power supply components must be given in the operational communications satellites.

The steps proposed for the advanced satellite flight program which will follow on beyond Relay and Syncom are shown on the next two charts. Performance improvement of the active satellite systems is the primary objective (chart F62-55). The first step in this direction is to take advantage of the growth that can come about as we move to larger launch vehicles. This is illustrated on this chart -- Relay uses the Delta vehicle. Delta will put a Relay satellite weighing 150 pounds into an elliptical orbit with seven hundred mile perigee and 3,000 miles apogee. With this type of orbit most of the data transmission can take place only when the 3,000 mile apogee is in the proper position with respect to the two terminal ground stations. The advanced low altitude satellite we are proposing will use a larger vehicle, the Atlas-Agena B. Here we can expect to put a 600 pound spacecraft into a circular orbit at an altitude over 6,000 miles and perhaps as high as 12,000 miles. The advantages to be gained from these weight and orbit changes will be shown on the next chart.

Insofar as the synchronous systems are concerned, Syncom also uses a Delta as a launch vehicle. Here the satellite weight including the apogee rocket is 125 pounds, of which the communications package itself is 55 pounds.

The Delta plus apogee rocket combination can be used to get the 55 pounds into a 22,300 mile altitude inclined orbit. By changing to the Atlas-Agena B we expect to bring the weight of the communications package for the advanced systems up to about 500 pounds and at the same time should have enough booster performance to get a truly equatorial orbit at 22,300 miles altitude.

If we now look at the second chart (F62-56) we find that the Relay satellite is designed to handle a single TV channel and only about ten percent of the time in orbit is useable for communications between the two major terminal points. Also Relay is essentially a two-station system which means communications can be passed back and forth only between a single pair of station. As we develop more advanced techniques for application to the low altitude system, and change to the larger launch vehicle, we hope to increase the capacity to four TV channels or its equivalent in telephone channels. By increasing the altitude in orbit by several thousands of miles the time available for transmission between a pair of typical stations should increase to twenty-five percent, and we would like to rework the electronic design of the satellite and the ground stations so that many stations can simultaneously have access to the satellite and so can then transmit to any of the other stations with a minimum of constraints.

The Syncom plans now call for a capability of transmitting at least one telephone channel. This restriction on message handling capacity is a result of having to work with a very lightweight satellite. Syncom will be launched into an inclined orbit, as I have noted before, and will be available for transmission between stations only about 75 percent of the time, chiefly because of its motion to either side of the equator. It too is a two-station system. An advanced synchronous system should increase the message handling capacity to four TV channels. With increased vehicle performance, we should obtain the true equatorial orbit, and the satellite should be available for 100 percent of the time. As in the low altitude system, the system design will be modified to provide for multiple station access to the satellite.

Before concluding, I would like to say a few words about the area of Future Applications that was indicated on my first chart (F62-48). There are two segments into which we can divide Future Applications -

one of these is other satellite applications. Typical of this sort of application might be a civilian navigational satellite effort. Navigational satellites are presently under development by the Navy in Project Transit and this program is coming along quite rapidly from a military point of view. There may be an area of civilian application for Transit and it is NASA's intention, to work with the Department of Defense and the Navy to explore this possibility.

The other segment of applications to which our office is directing its attention is that of identifying within the NASA research and development program those new techniques or processes which can be used by a wide range of industrial organizations. This chart (F62-58) has been prepared to indicate what we think we must do to accelerate the process of getting this new data to potential users. First, we must recognize a process, material, or device as having potential industrial value. Then, we must catalog the useful properties or values so that we can refer the new development to anyone who has an interest in a specified area. Third, we must take action to inform those whom we think have potential use for the new idea, so that as rapidly as possible, the benefits of new developments are fed out to the various segments of industry which can make use of it. Finally, we will have to continuously evaluate and refine our procedures for processing applications information, so that we arrive at the most effective way of accomplishing the three activities just discussed.

In summary, the Office of Applications has three major areas of activity in its program, these are meteorological systems, the communications systems and future applications. The first two of these are programs for satellite systems development. A specific line of satellite development is already underway in meteorological systems.

In communications we feel that quite probably the ultimate system may use the synchronous orbit satellite. As this is a difficult technical development, in the interim, efforts leading to the establishment of a communications satellite system using low or intermediate altitude active repeaters have been initiated. At the same time, since the ultimate value of the passive satellite in the range of possible communications satellite systems is not determined, we are continuing to investigate the construction and utility of passive satellites. The experimental work on the synchronous satellite will be used in the development and evaluation of techniques, which if proven feasible, should make it possible to realize an operational system within a reasonable period of time. In the area of Future Applications, our present effort is to locate within the NASA's research and development program those new techniques, processes and devices which can be of benefit to the civilian economy.

OFFICE OF APPLICATIONS

- METEOROLOGY
- COMMUNICATIONS
- FUTURE APPLICATIONS

F 62-63

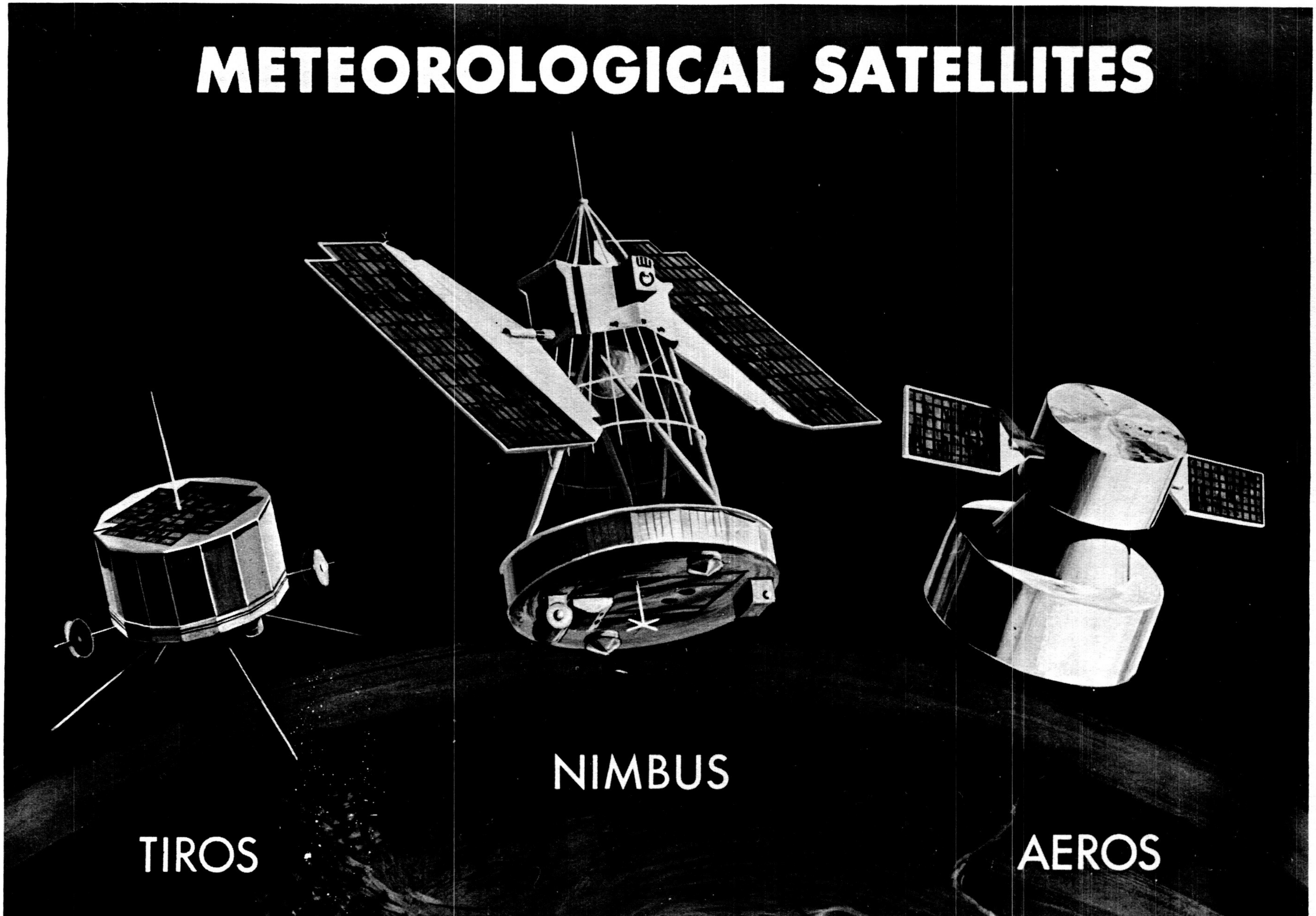
METEOROLOGICAL SYSTEMS

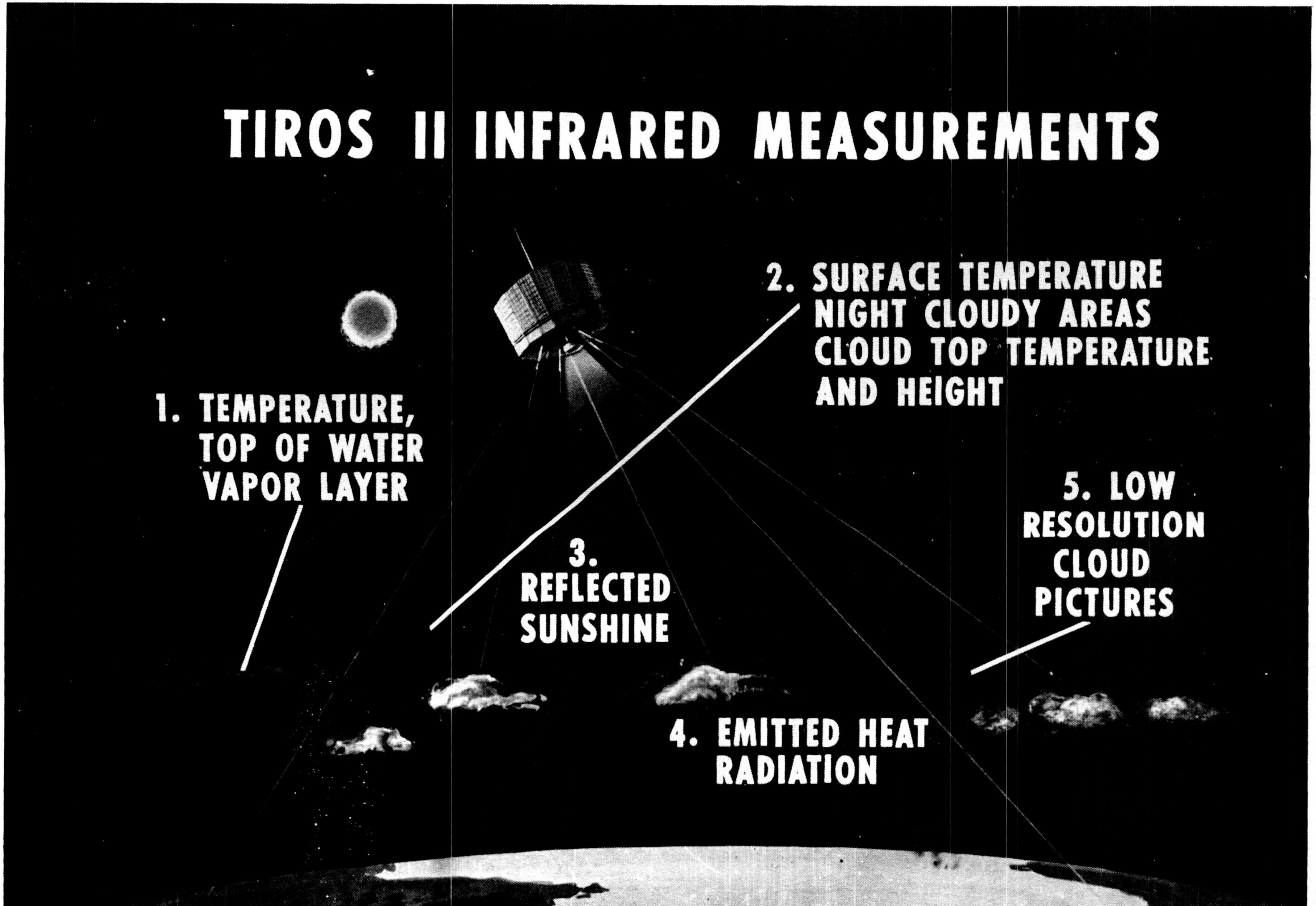
F 62-64

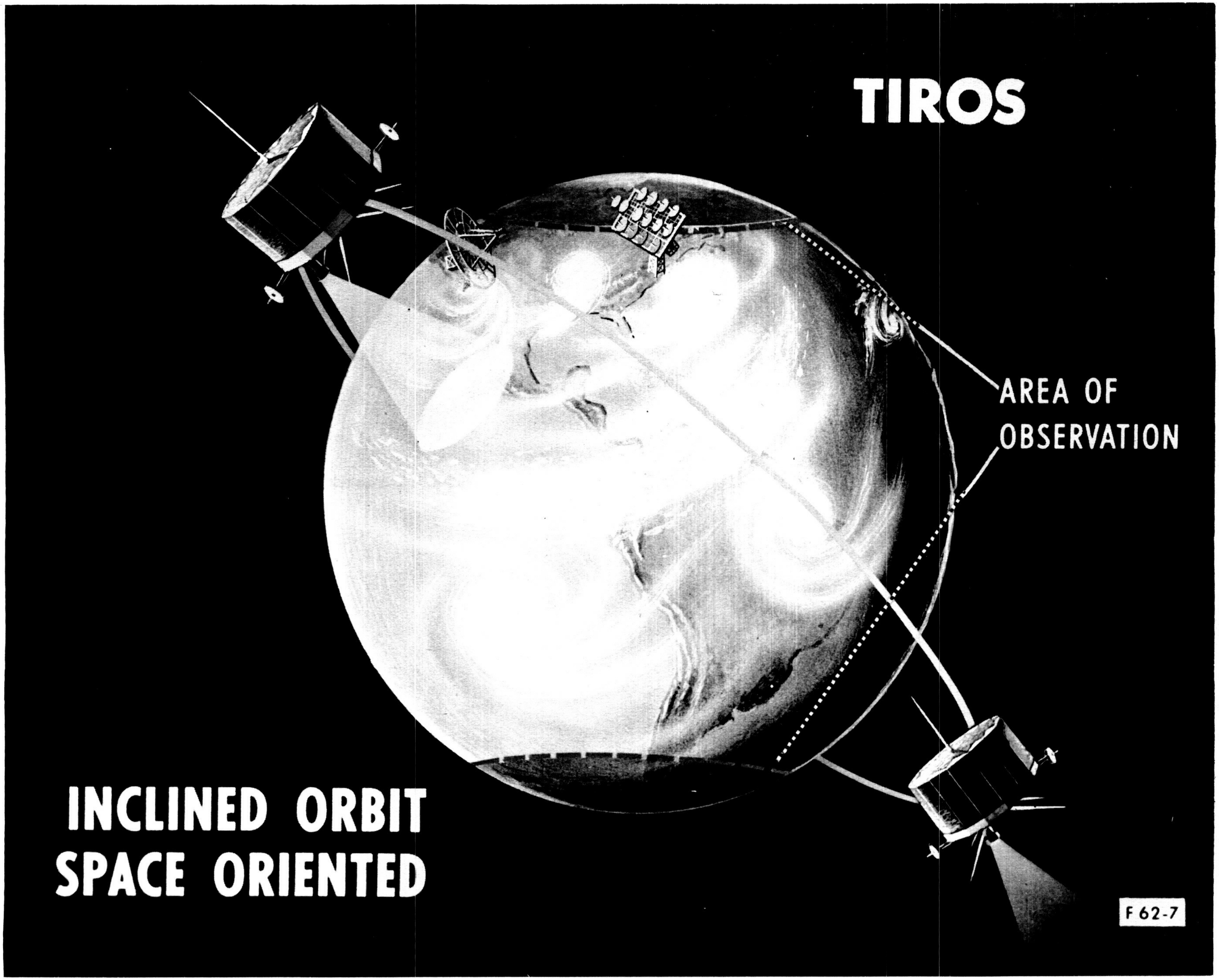
METEOROLOGICAL SYSTEMS
PROGRAM OBJECTIVES

- DEVELOP EQUIPMENT AND TECHNIQUES REQUIRED FOR:
  - ▸ OPERATIONAL METEOROLOGICAL SATELLITE SYSTEMS
  - ▸ SUPPORT OF METEOROLOGICAL RESEARCH
- SATELLITE LAUNCHINGS FOR:
  - ▸ CONTINUED DEVELOPMENT OF SENSORS, SPACECRAFT AND SYSTEMS
  - ▸ INTERIM OPERATIONAL USE BY THE WEATHER SERVICES
- ESTABLISH, WITH THE WEATHER BUREAU, AN OPERATIONAL METEOROLOGICAL SATELLITE SYSTEM
- DEVELOP SOUNDING ROCKET TECHNIQUES FOR METEOROLOGICAL APPLICATIONS

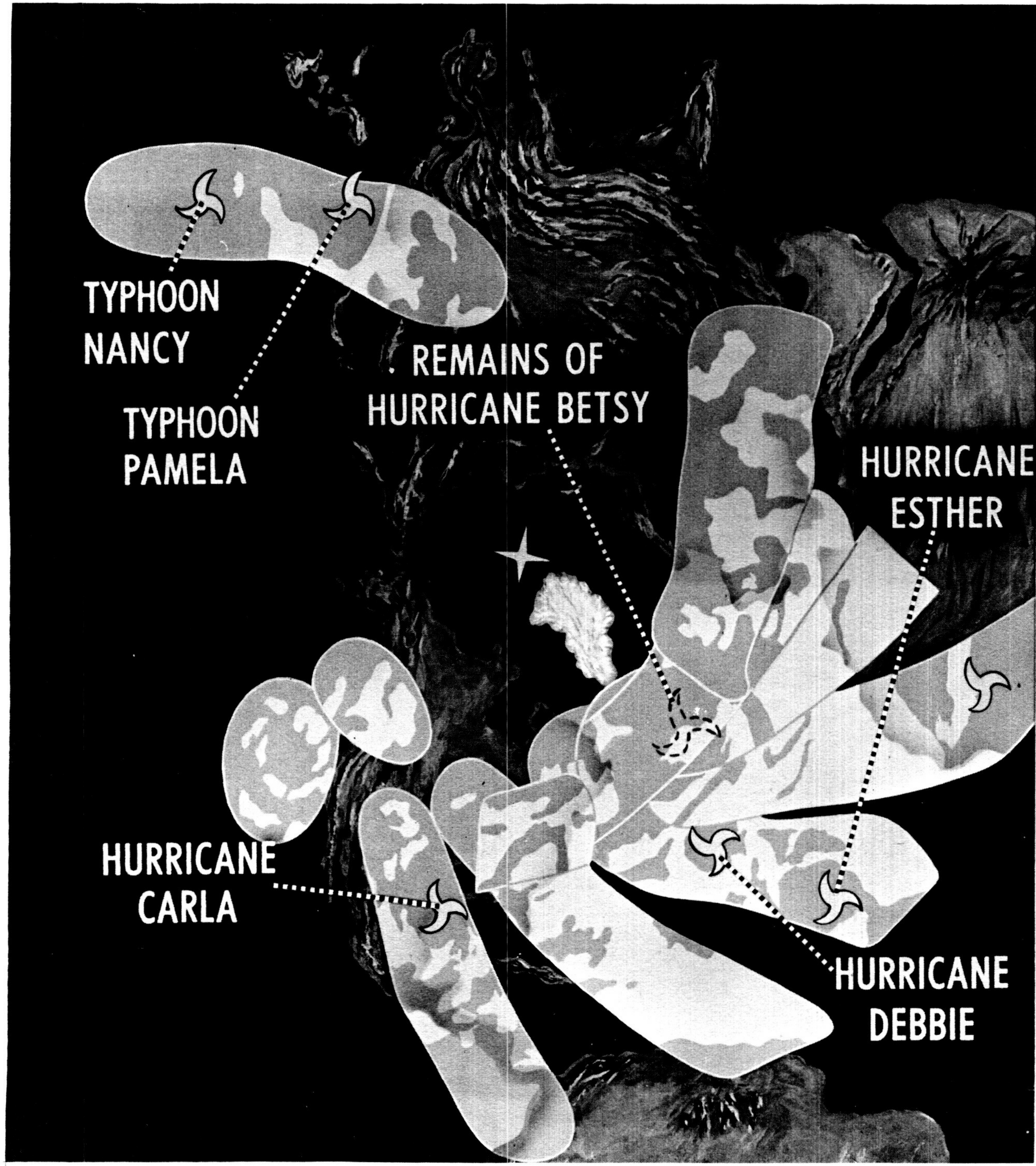
F 62-2


METEOROLOGICAL SATELLITES
TIROS
NIMBUS
AEROS
F 62-3


TIROS II INFRARED MEASUREMENTS
1. TEMPERATURE, TOP OF WATER VAPOR LAYER
2. SURFACE TEMPERATURE NIGHT CLOUDY AREAS CLOUD TOP TEMPERATURE AND HEIGHT
3. REFLECTED SUNSHINE
4. EMITTED HEAT RADIATION
5. LOW RESOLUTION CLOUD PICTURES
61-95


TIROS
AREA OF
OBSERVATION
INCLINED ORBIT
SPACE ORIENTED
F 62-7

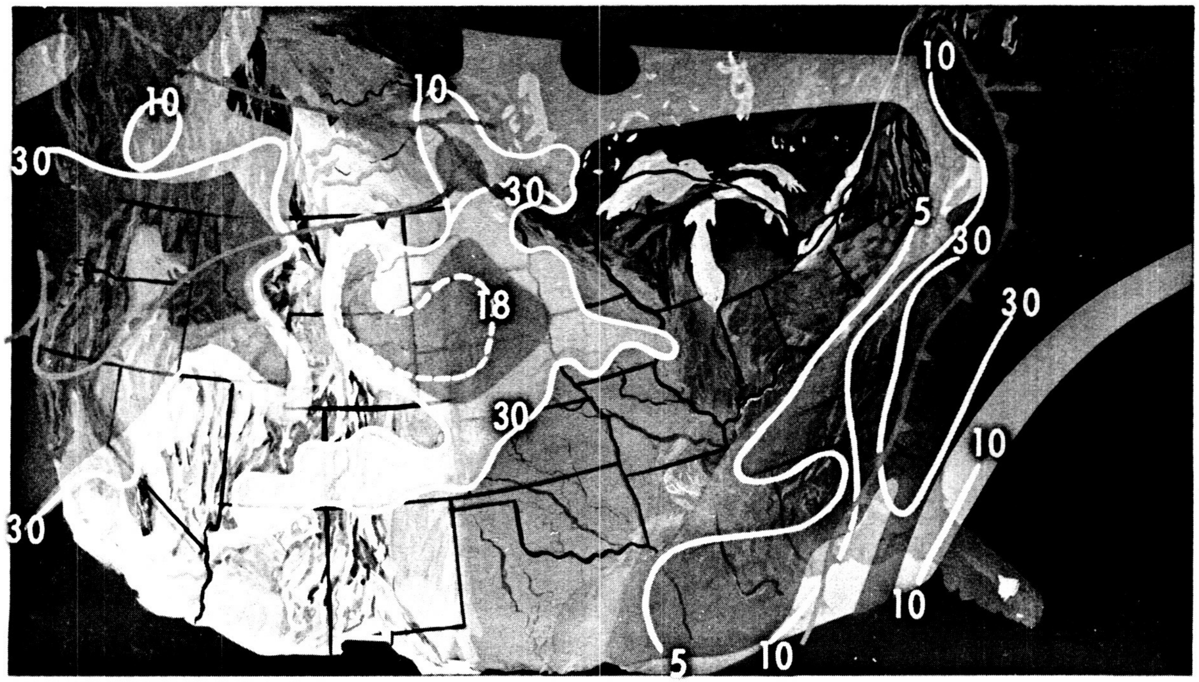

HURRICANE BETSY-WESTERN ATLANTIC OCEAN
SEPT 7, 1961
F 62-9



GLOBAL CLOUD ANALYSIS SEPT. 11 1961

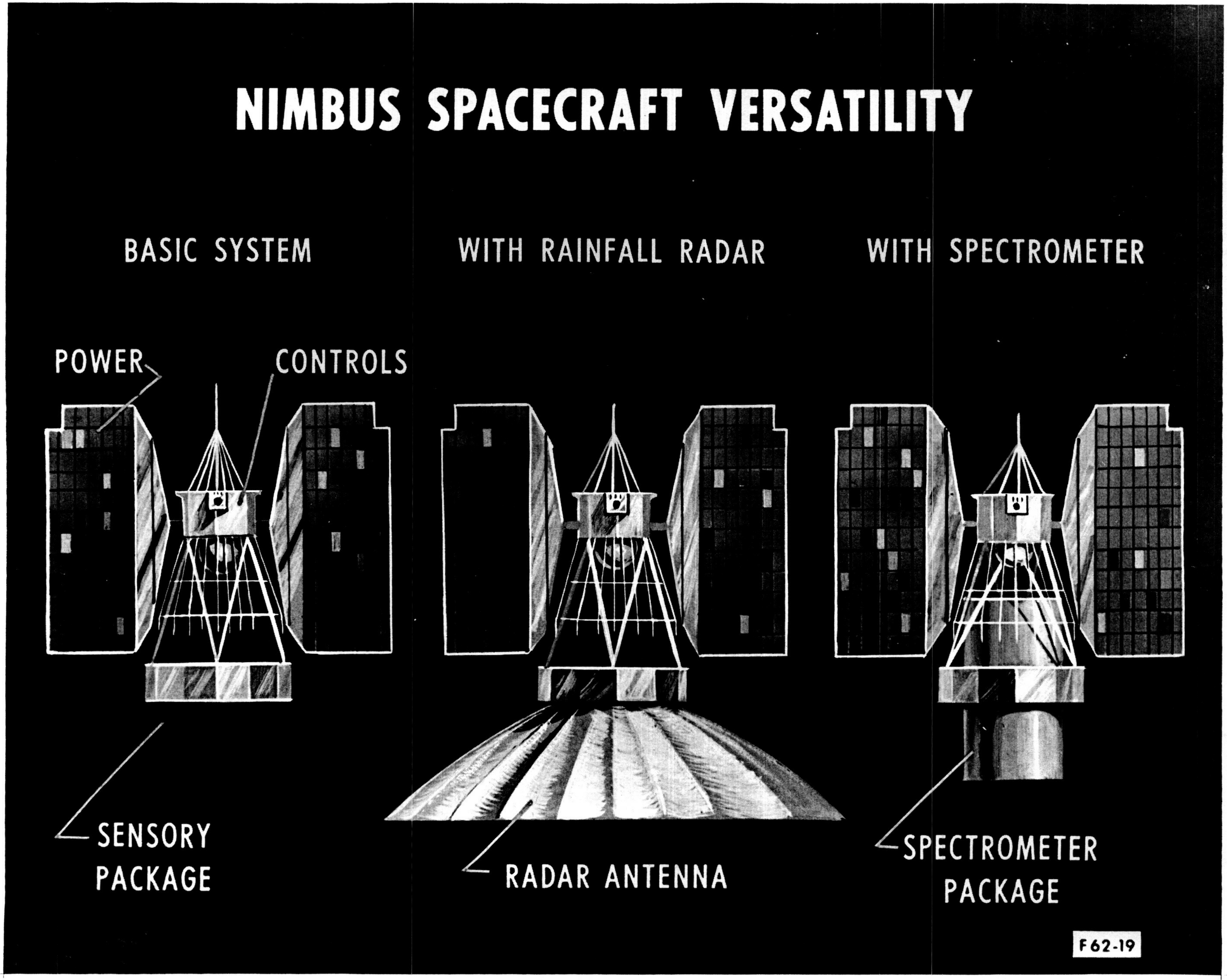
F 62-10

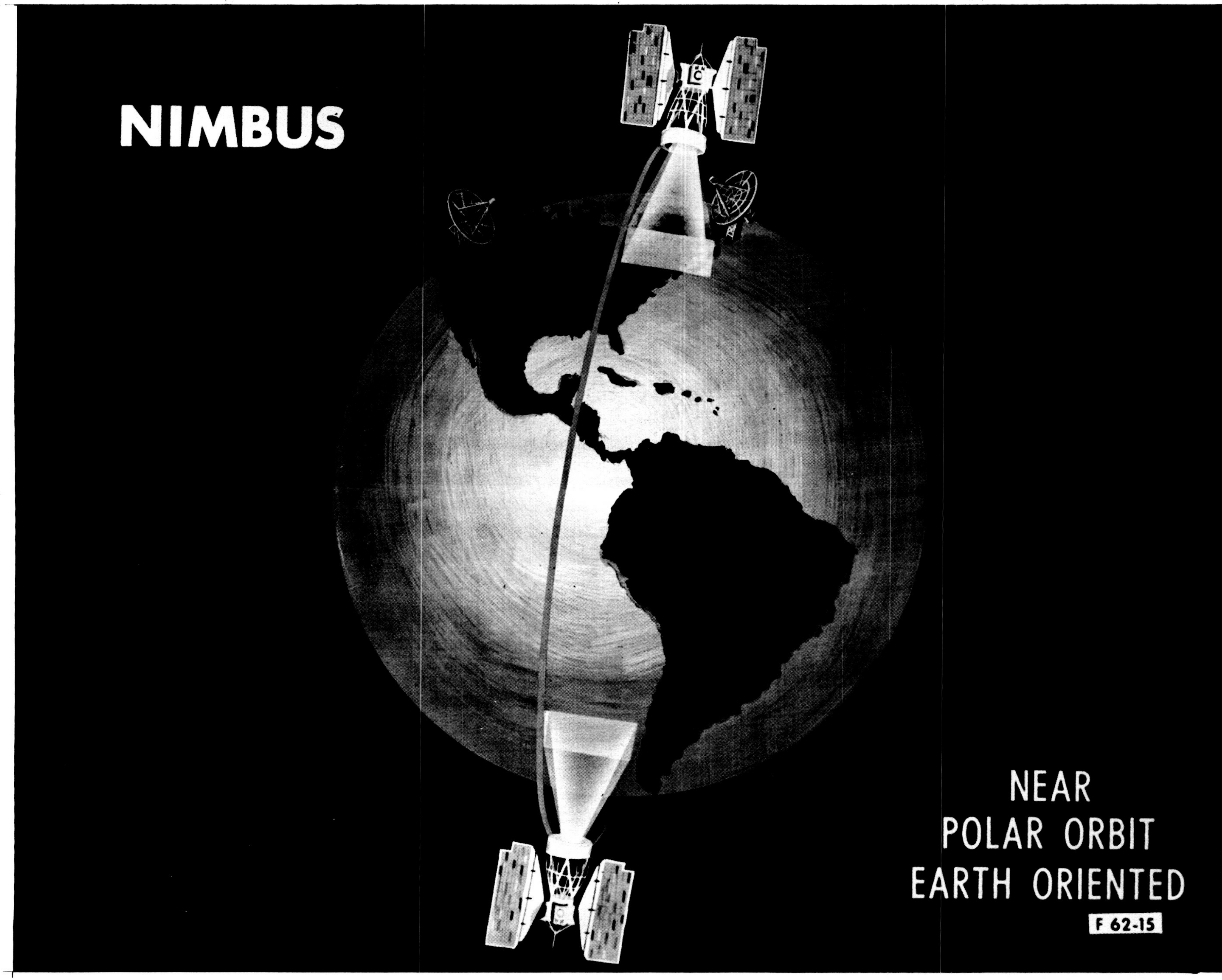
MAP OF TIROS II INFRARED DATA

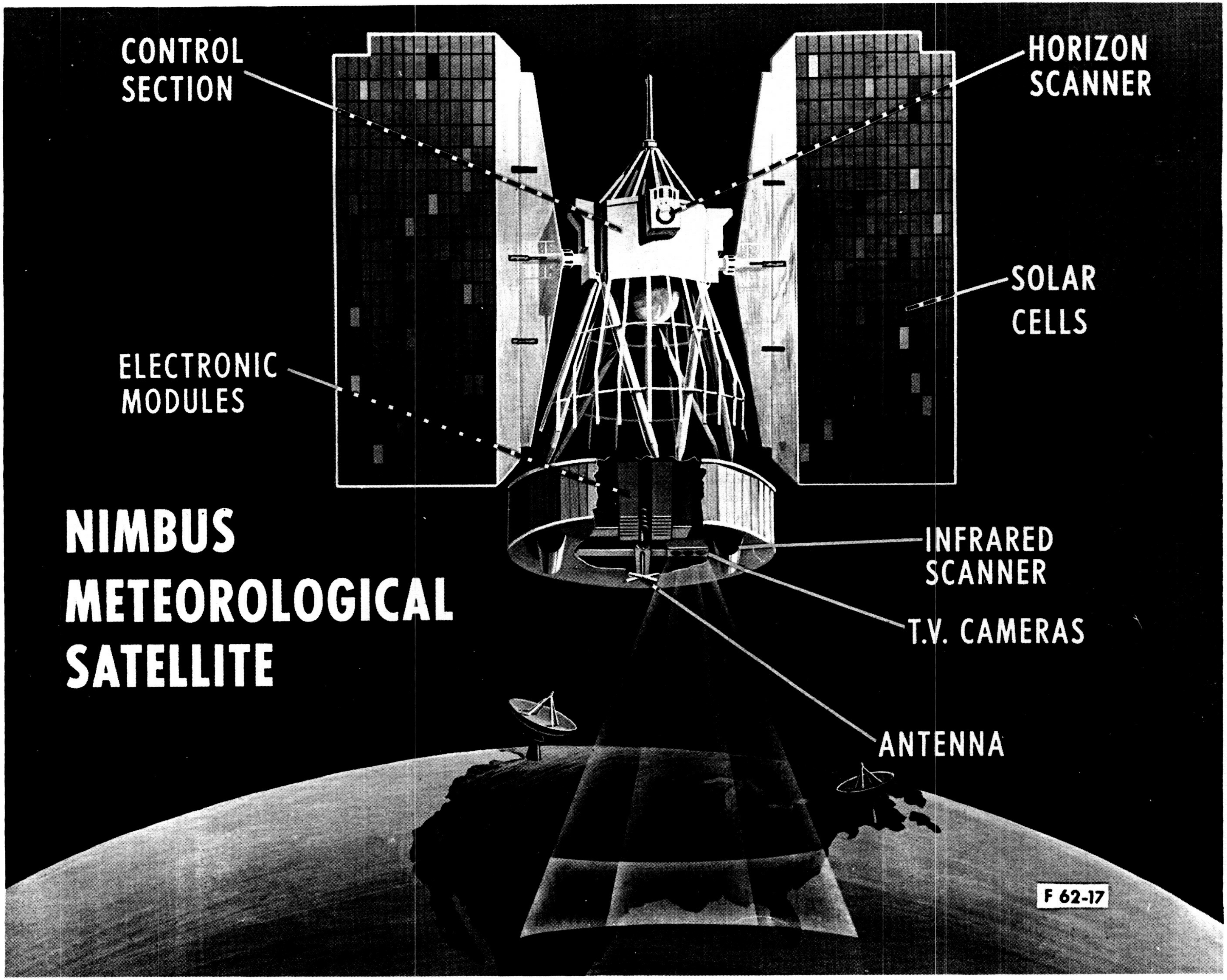


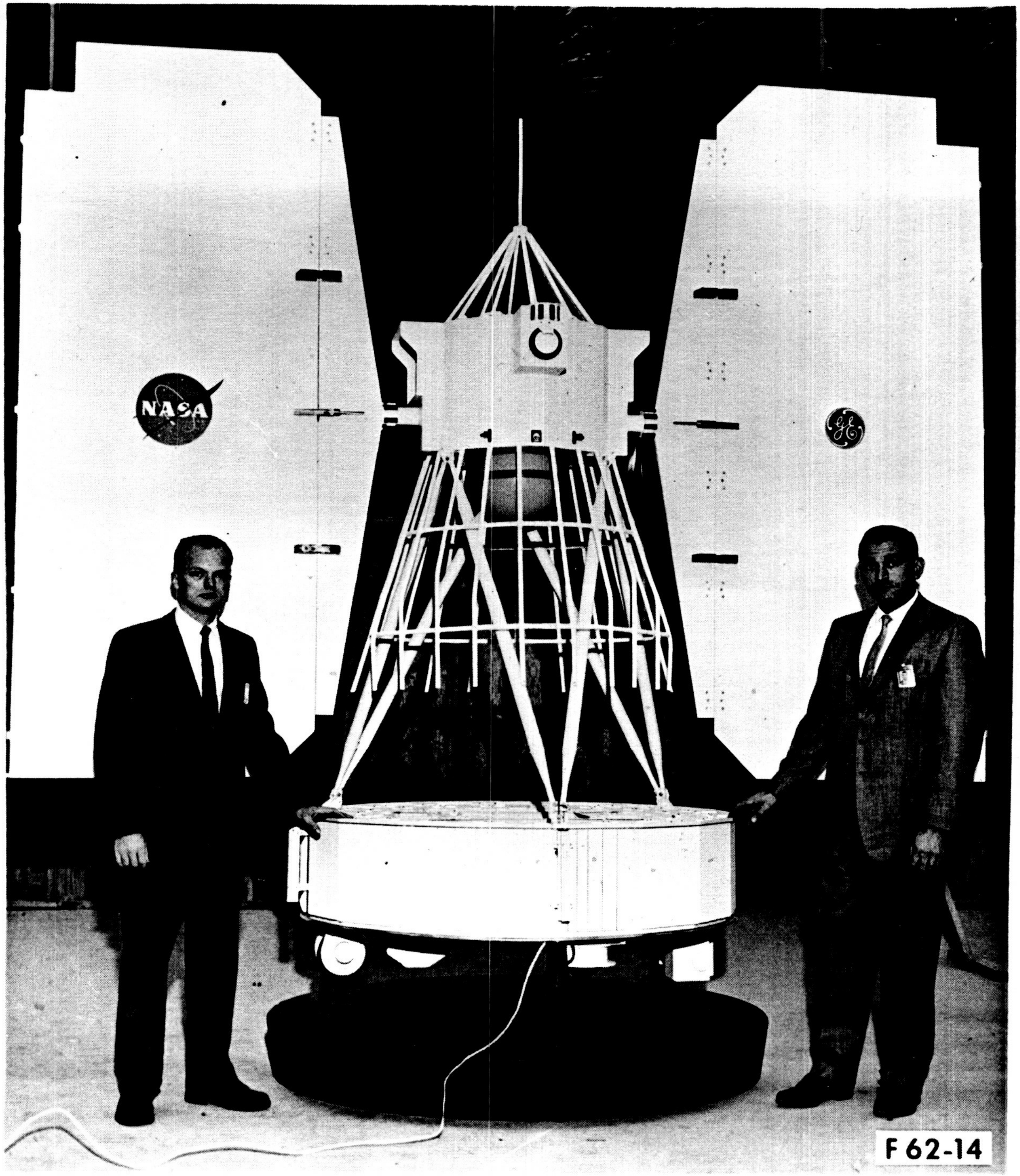
CLOUD ANALYSIS SIMULTANEOUS WITH INFRARED DATA

F 62-12


NIMBUS SPACECRAFT VERSATILITY
BASIC SYSTEM
WITH RAINFALL RADAR
WITH SPECTROMETER
POWER
CONTROLS
SENSORY PACKAGE
RADAR ANTENNA
SPECTROMETER PACKAGE
F62-19


NIMBUS
NEAR
POLAR ORBIT
EARTH ORIENTED
F 62-15

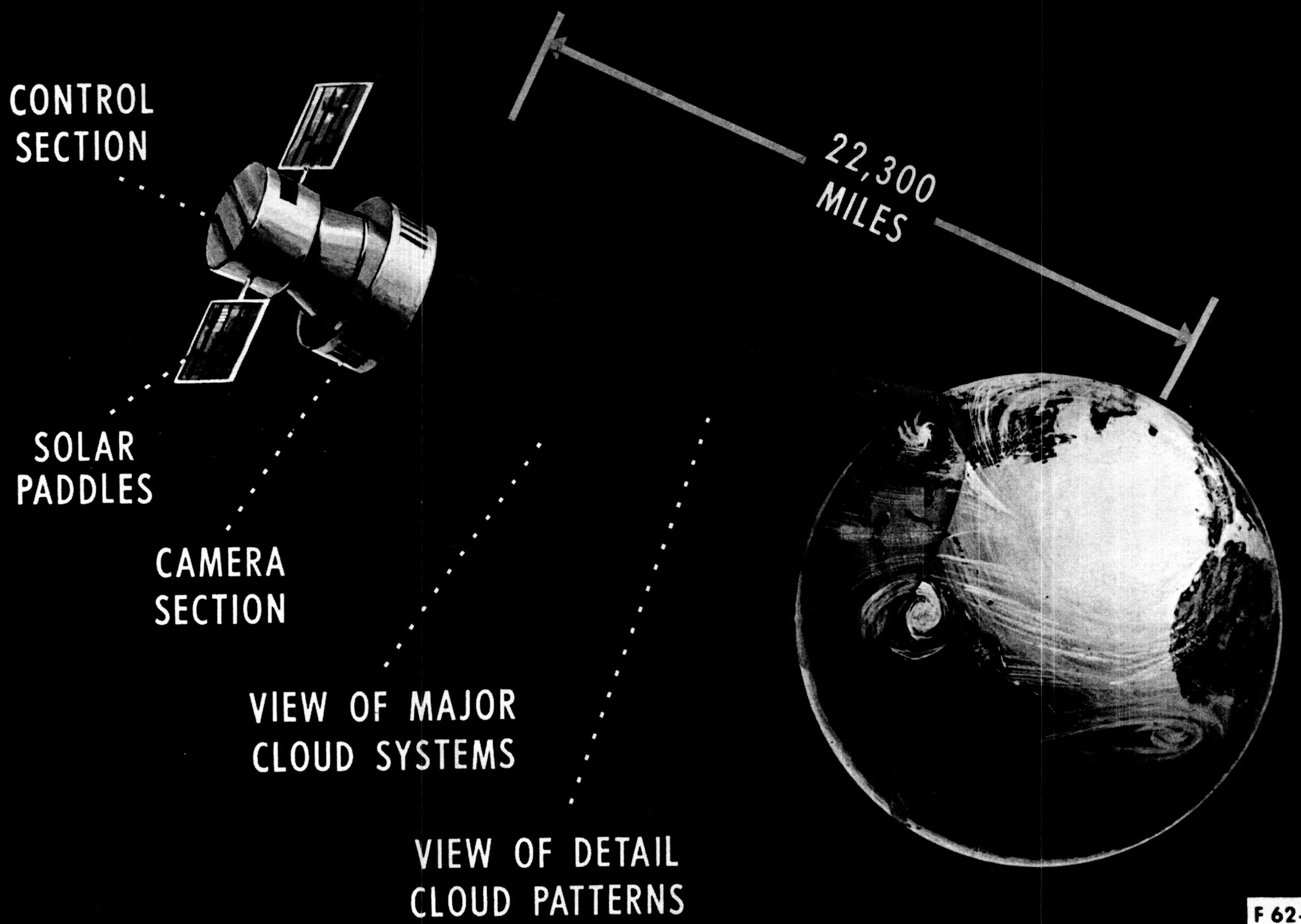

CONTROL SECTION
HORIZON SCANNER
SOLAR CELLS
ELECTRONIC MODULES
NIMBUS METEOROLOGICAL SATELLITE
INFRARED SCANNER
T.V. CAMERAS
ANTENNA
F 62-17



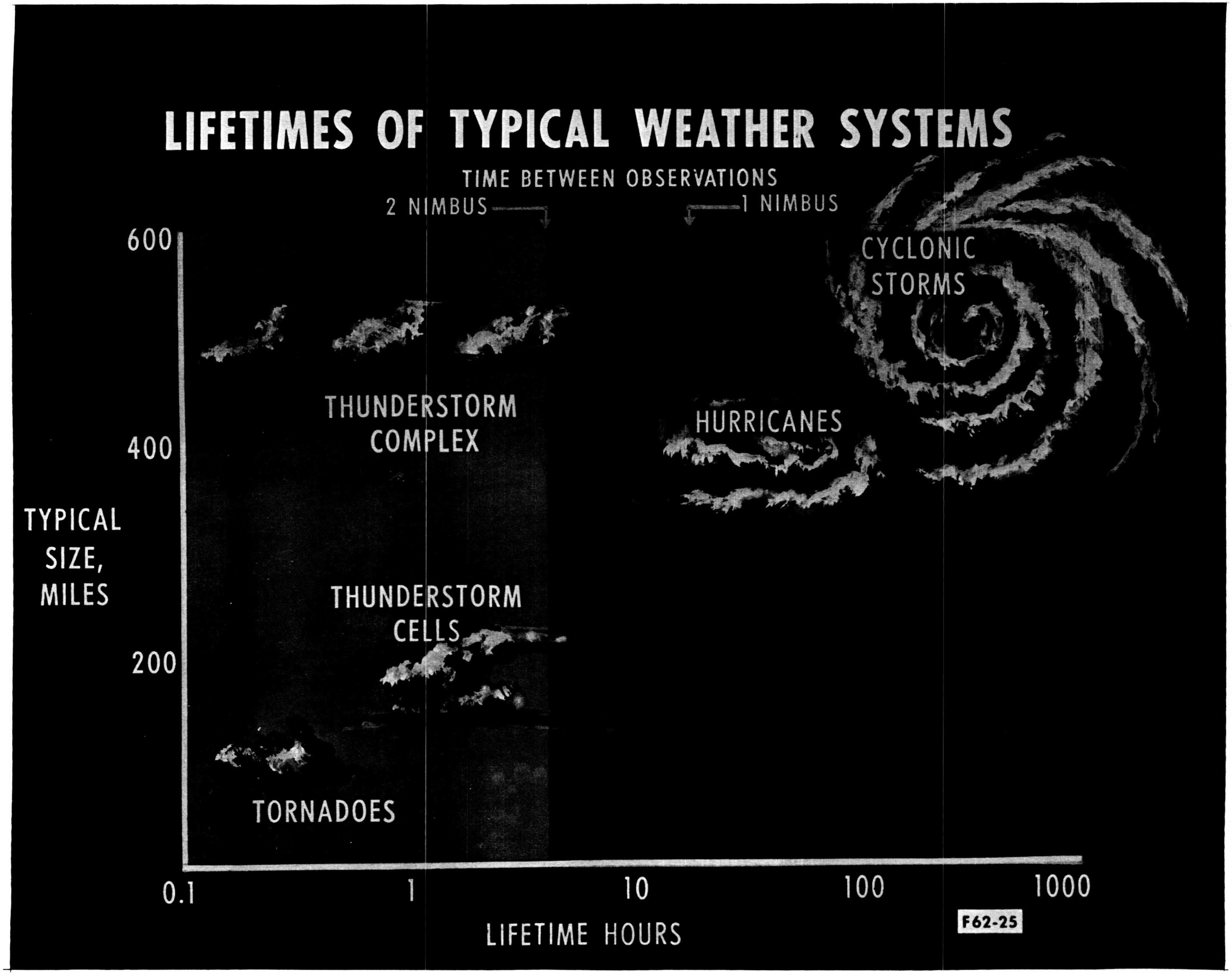
NIMBUS

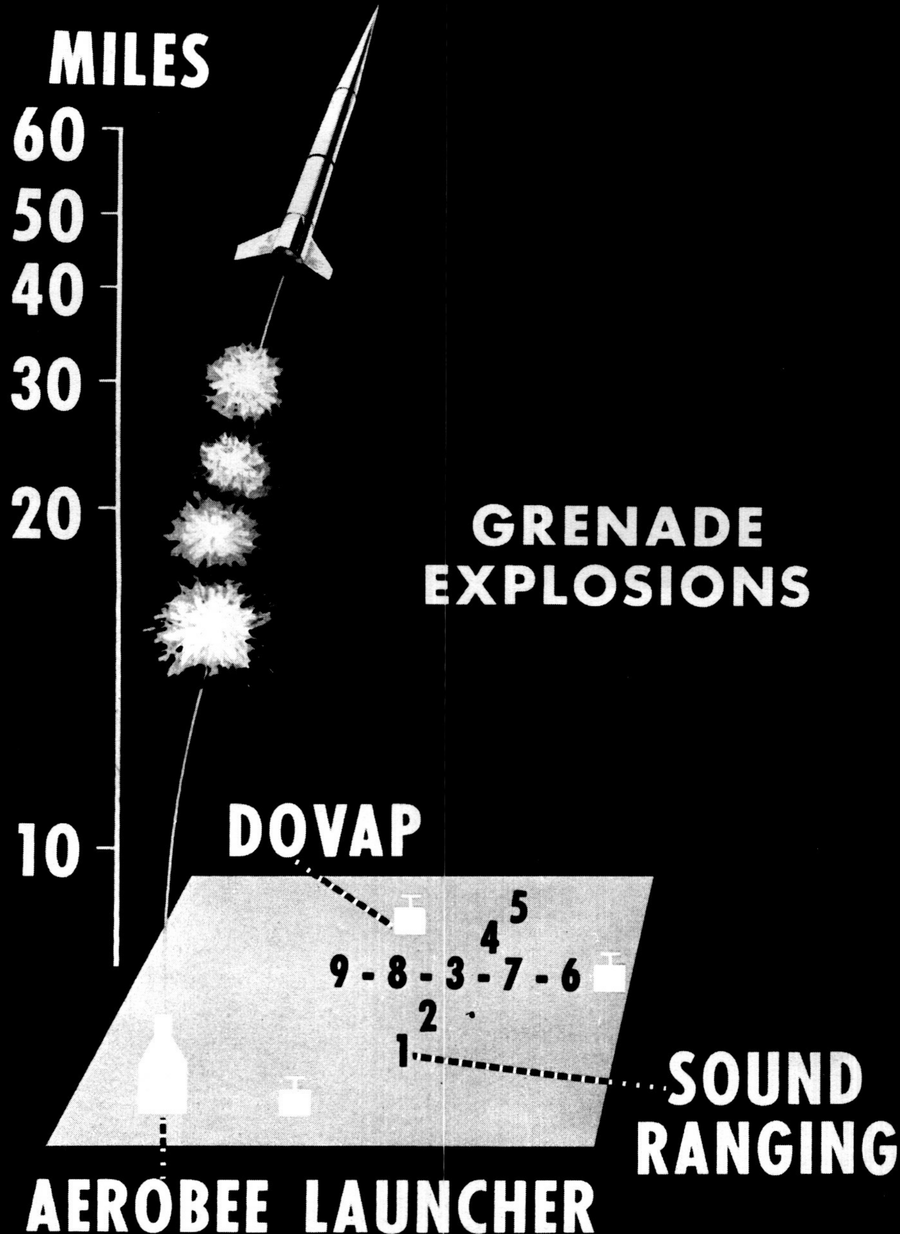
10

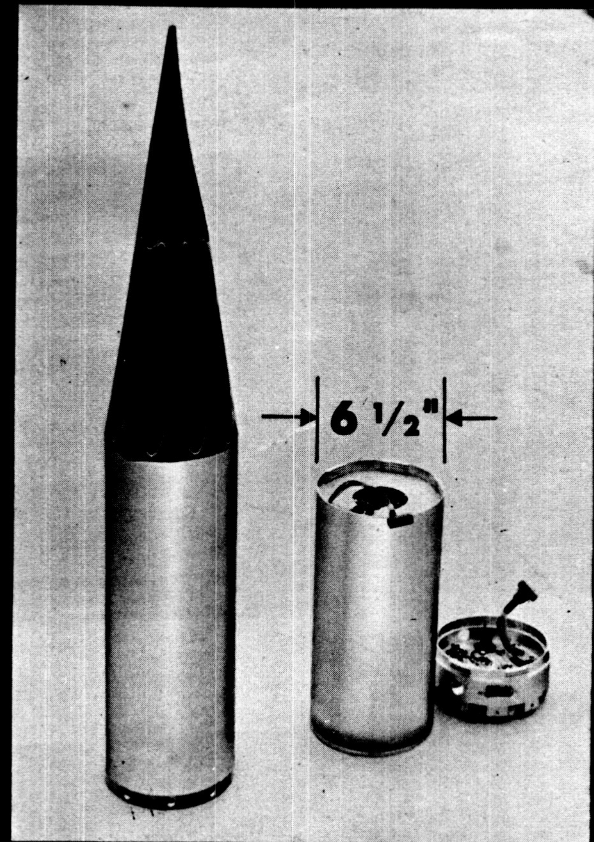
AEROS METEOROLOGICAL SATELLITE



F 62-24

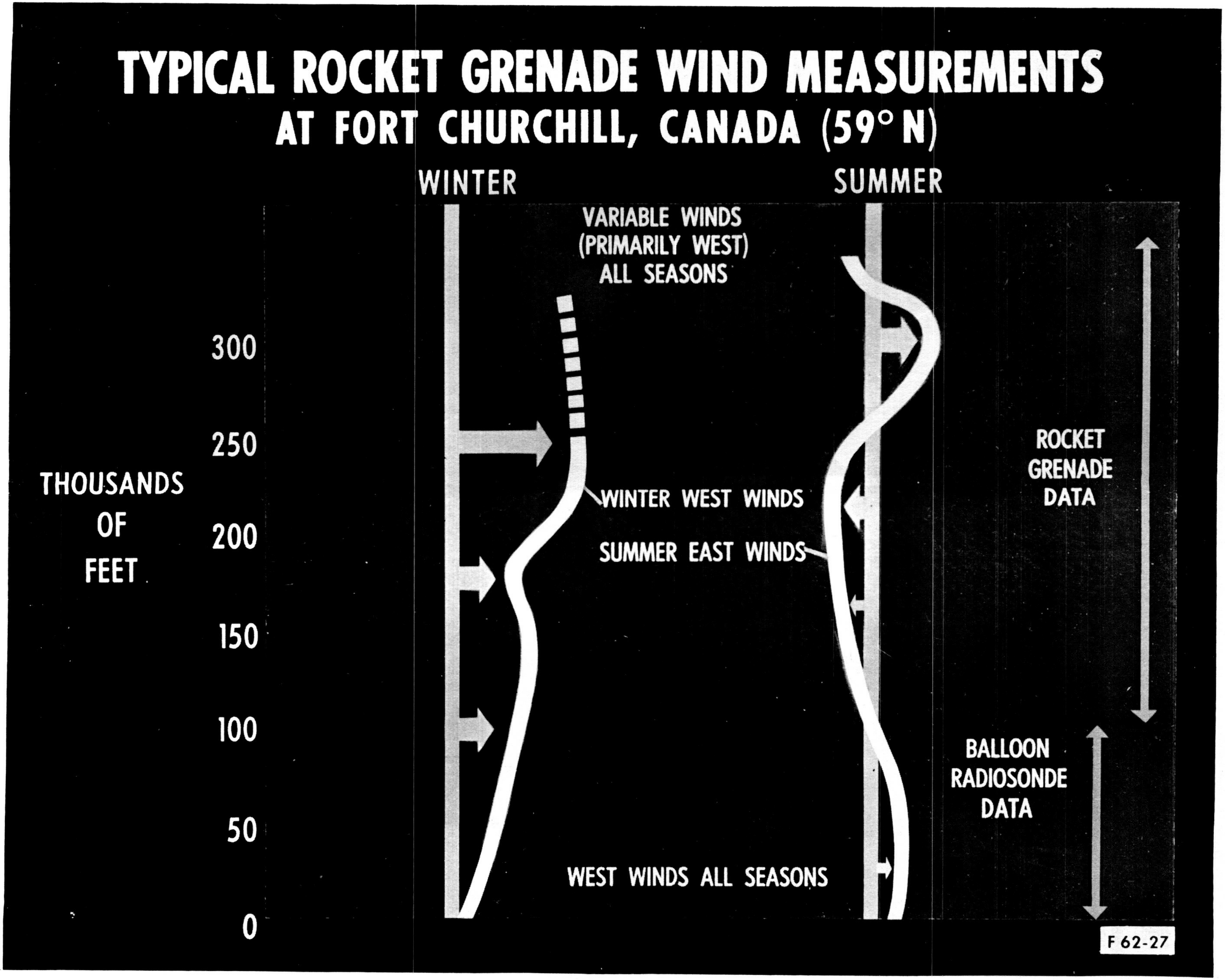

LIFETIMES OF TYPICAL WEATHER SYSTEMS
TIME BETWEEN OBSERVATIONS
2 NIMBUS
1 NIMBUS
TYPICAL SIZE, MILES
600
400
200
THUNDERSTORM COMPLEX
THUNDERSTORM CELLS
TORNADOES
HURRICANES
CYCLONIC STORMS
0.1
1
10
100
1000
LIFETIME HOURS
F62-25





METEOROLOGICAL
SOUNDING
ROCKETS

F 62-26


TYPICAL ROCKET GRENADE WIND MEASUREMENTS
AT FORT CHURCHILL, CANADA (59° N)
WINTER
SUMMER
THOUSANDS OF FEET
300
250
200
150
100
50
0
VARIABLE WINDS (PRIMARILY WEST) ALL SEASONS
WINTER WEST WINDS
SUMMER EAST WINDS
WEST WINDS ALL SEASONS
ROCKET GRENADE DATA
BALLOON RADIOSONDE DATA
F 62-27

COMMUNICATIONS SYSTEMS

F62-65

COMMUNICATIONS SYSTEMS PROGRAM OBJECTIVES

- DEMONSTRATION OF FEASIBILITY OF ACTIVE AND PASSIVE COMMUNICATIONS SATELLITE TECHNIQUES
- ESTABLISHMENT OF OPERATIONAL COMMUNICATIONS SATELLITE SYSTEMS
- SUPPORT OF OPERATIONAL COMMUNICATIONS SATELLITE SYSTEMS THROUGH CONTINUED RESEARCH, DEVELOPMENT AND FLIGHT TEST

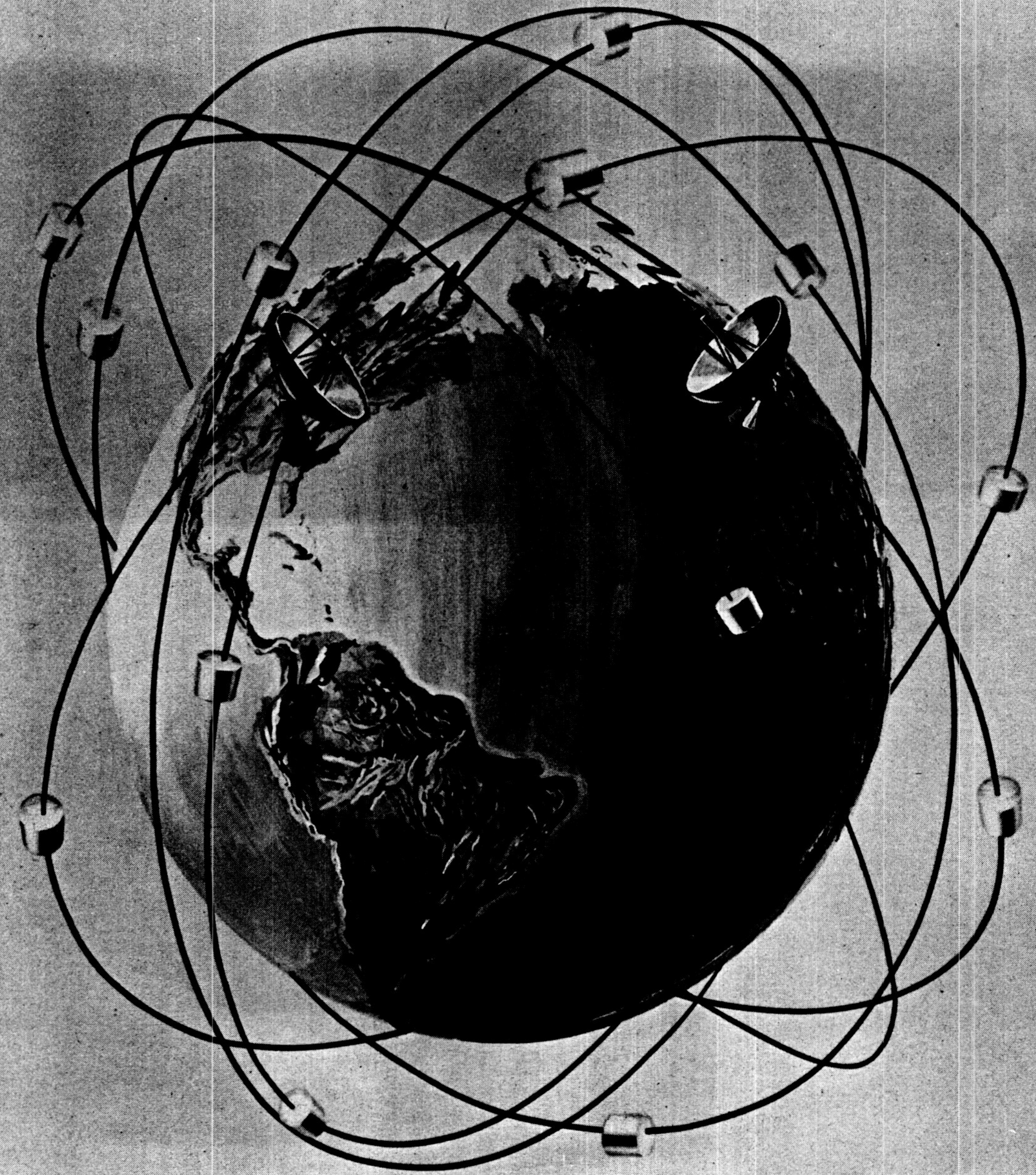
F 62-29

TYPES OF COMMUNICATIONS SATELLITE SYSTEMS

- LOW OR INTERMEDIATE ALTITUDE PASSIVE REFLECTORS
- LOW OR INTERMEDIATE ALTITUDE ACTIVE REPEATERS
- HIGH ALTITUDE, SYNCHRONOUS, ACTIVE REPEATERS

F 62-30

ACTIVE COMMUNICATIONS SATELLITES
LOW ALTITUDE ORBITS



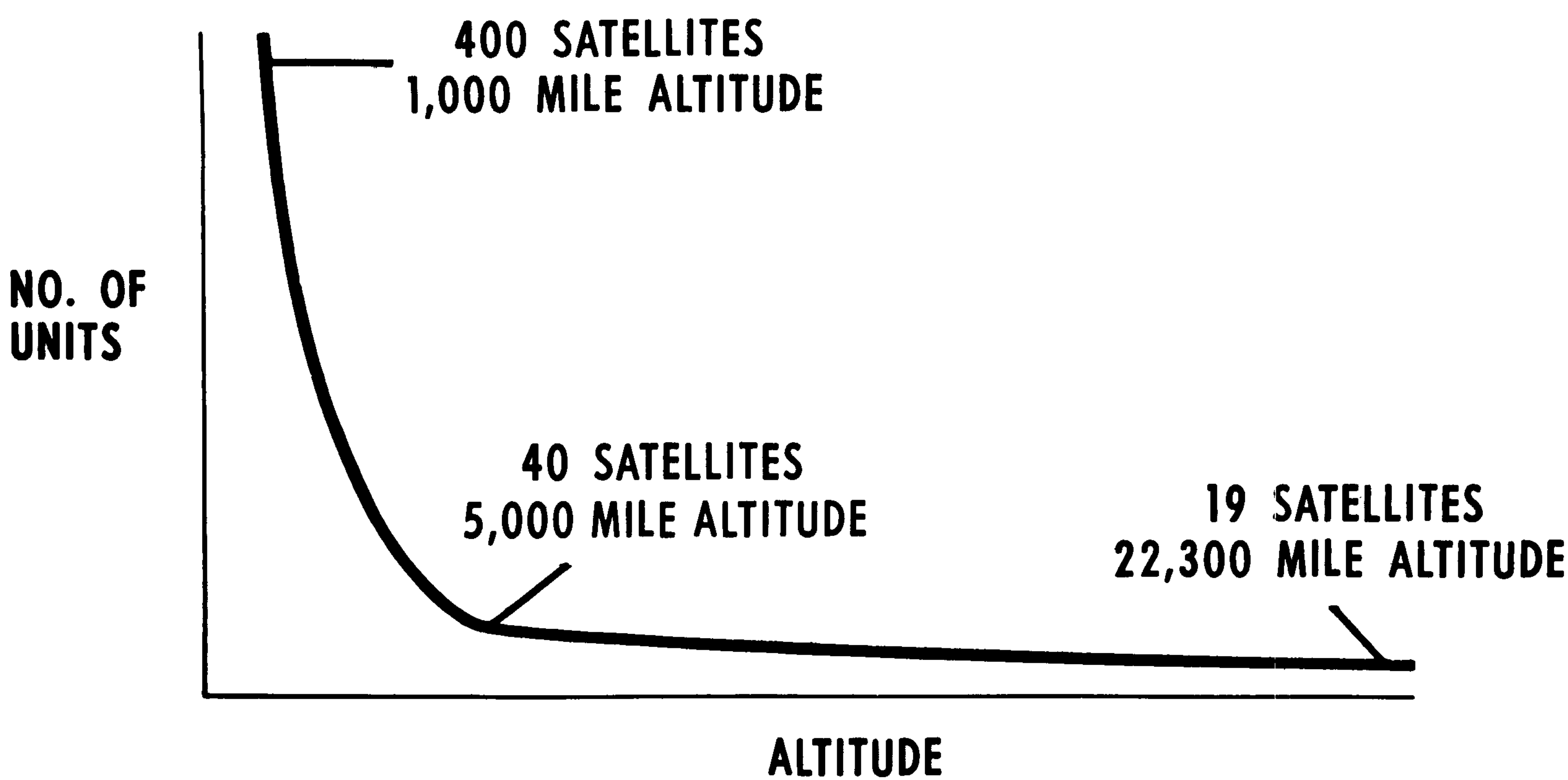
F 62-31

15

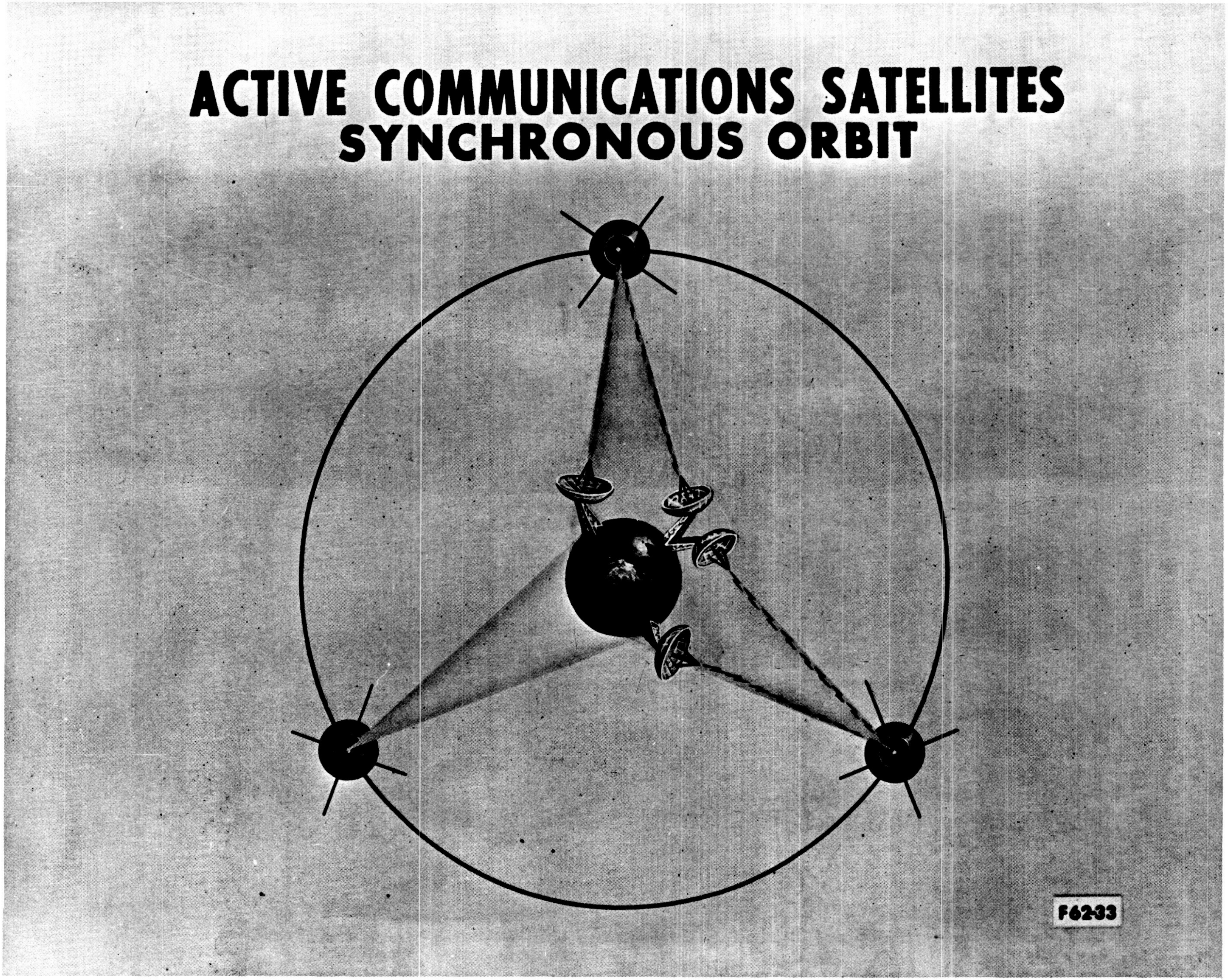
COMMUNICATION SATELLITES

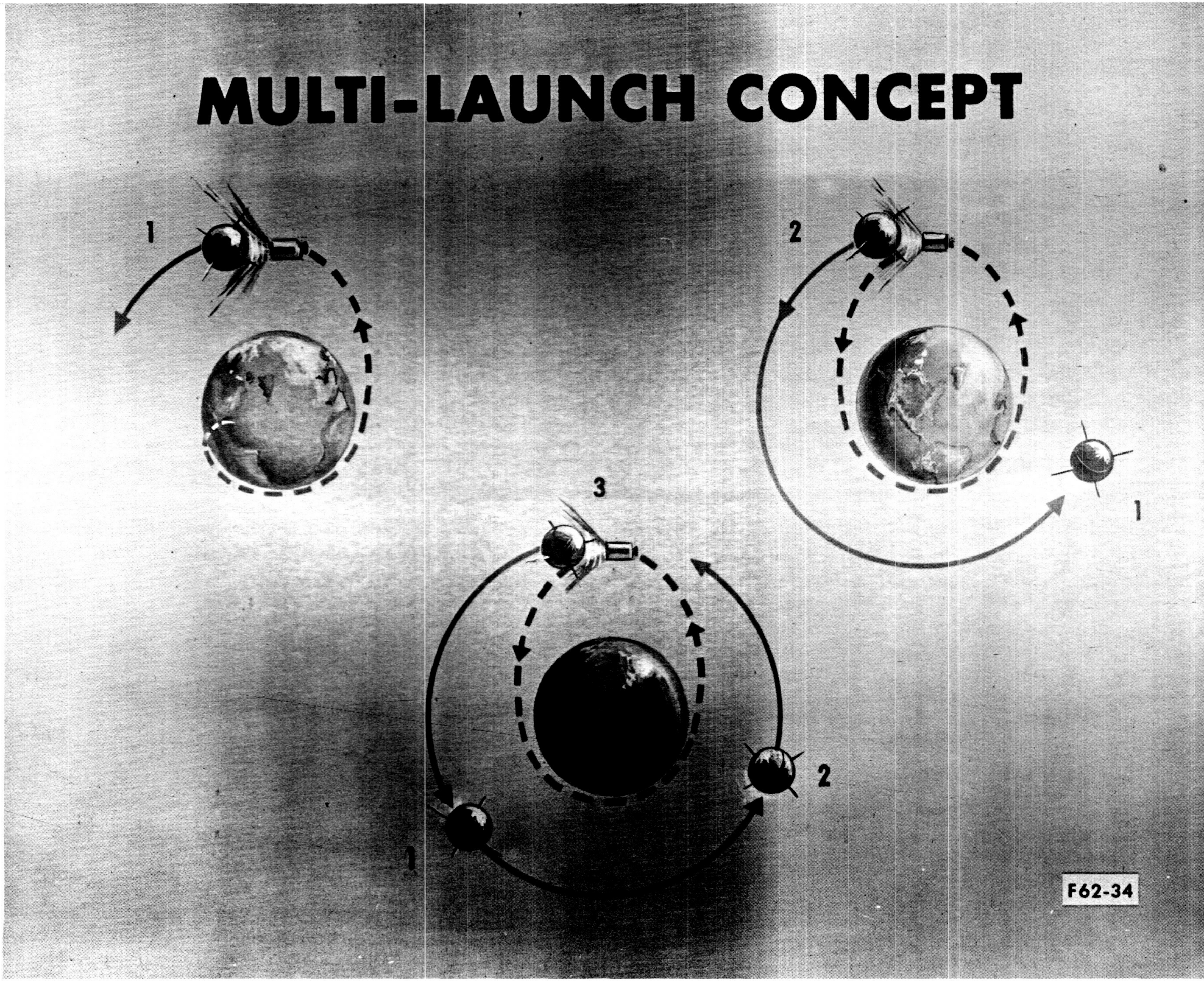
RANDOMLY SPACED

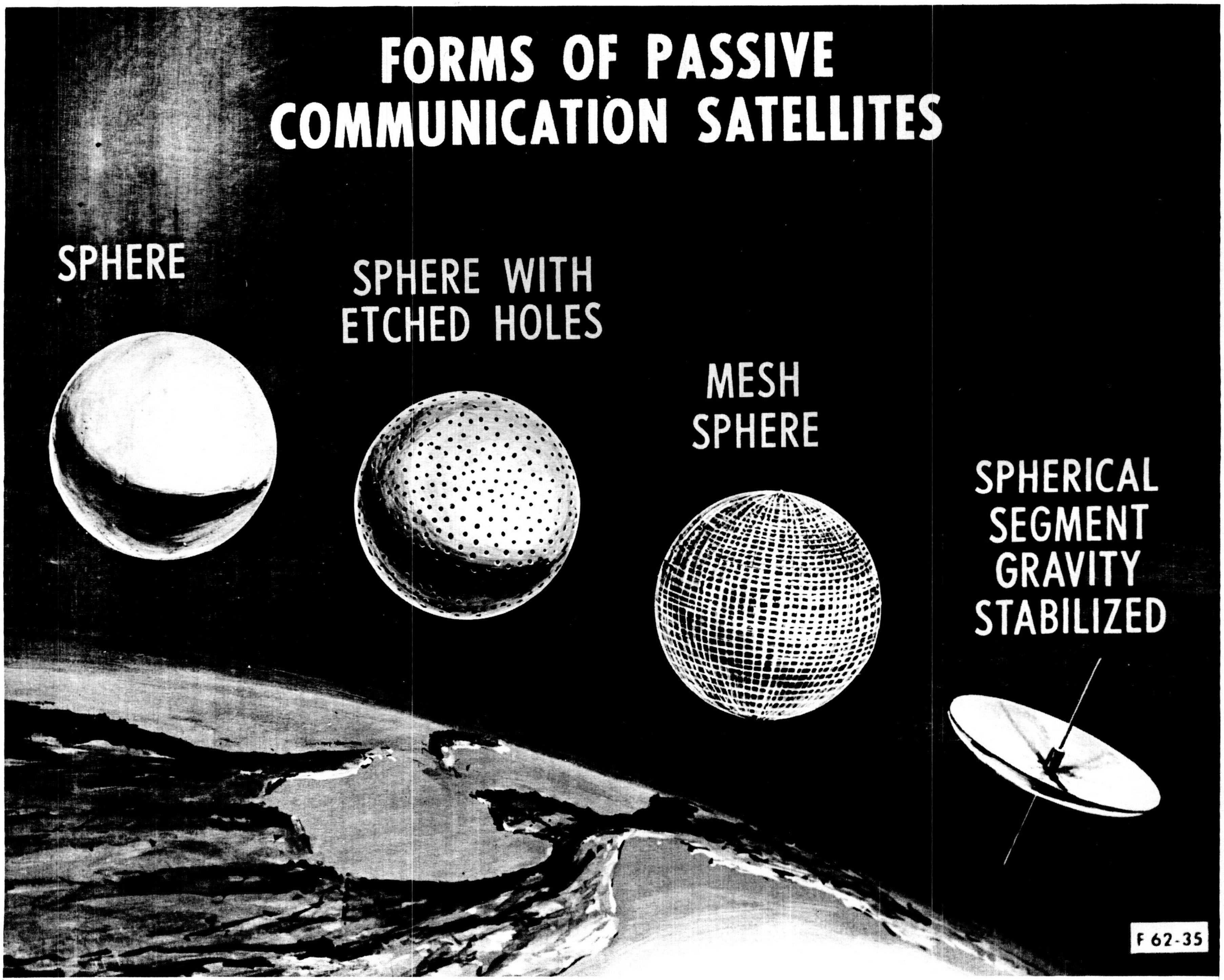
SUBSTANTIALLY CONTINUOUS SERVICE BETWEEN
GROUND TERMINALS 3000 MILES APART

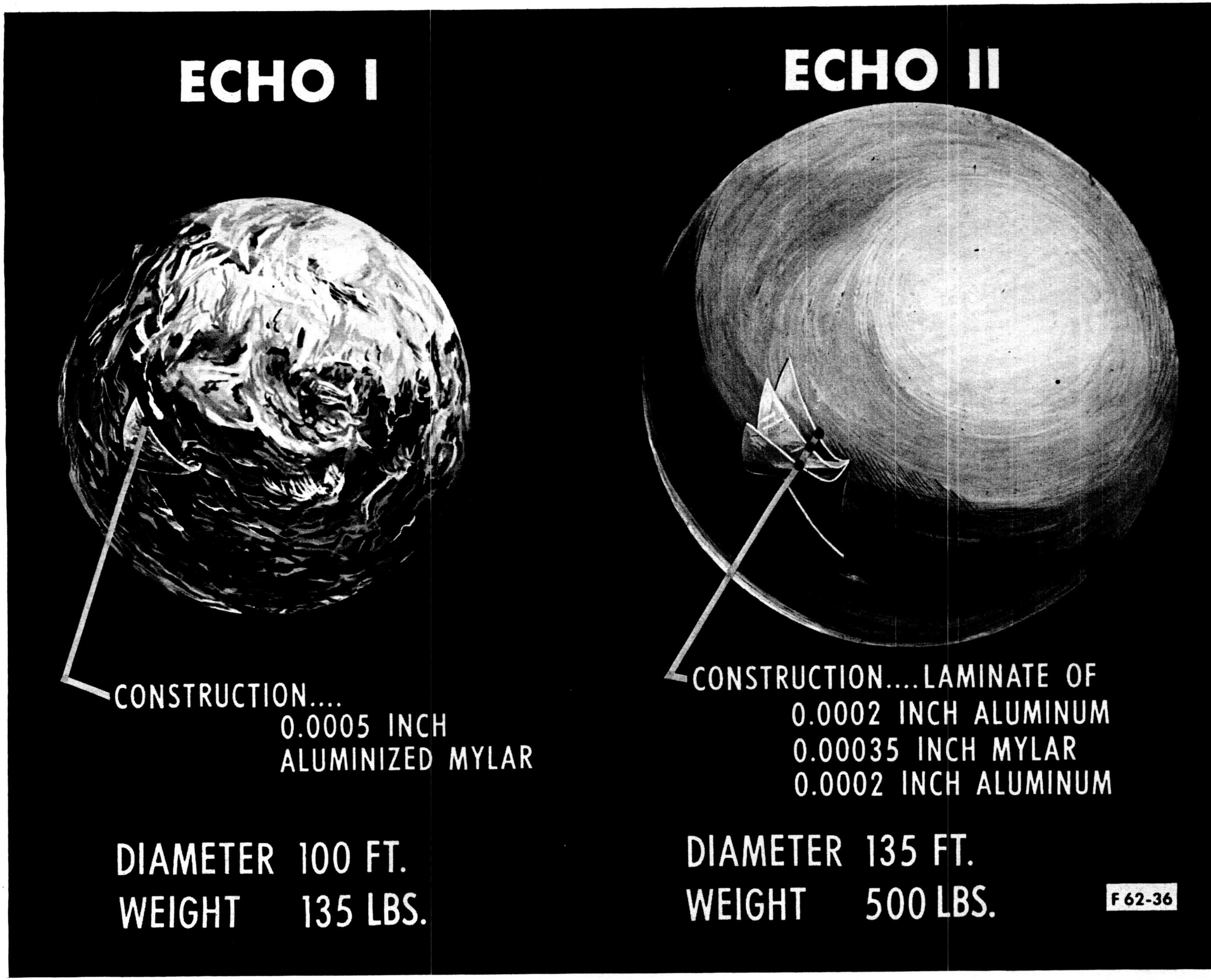


F 62-32

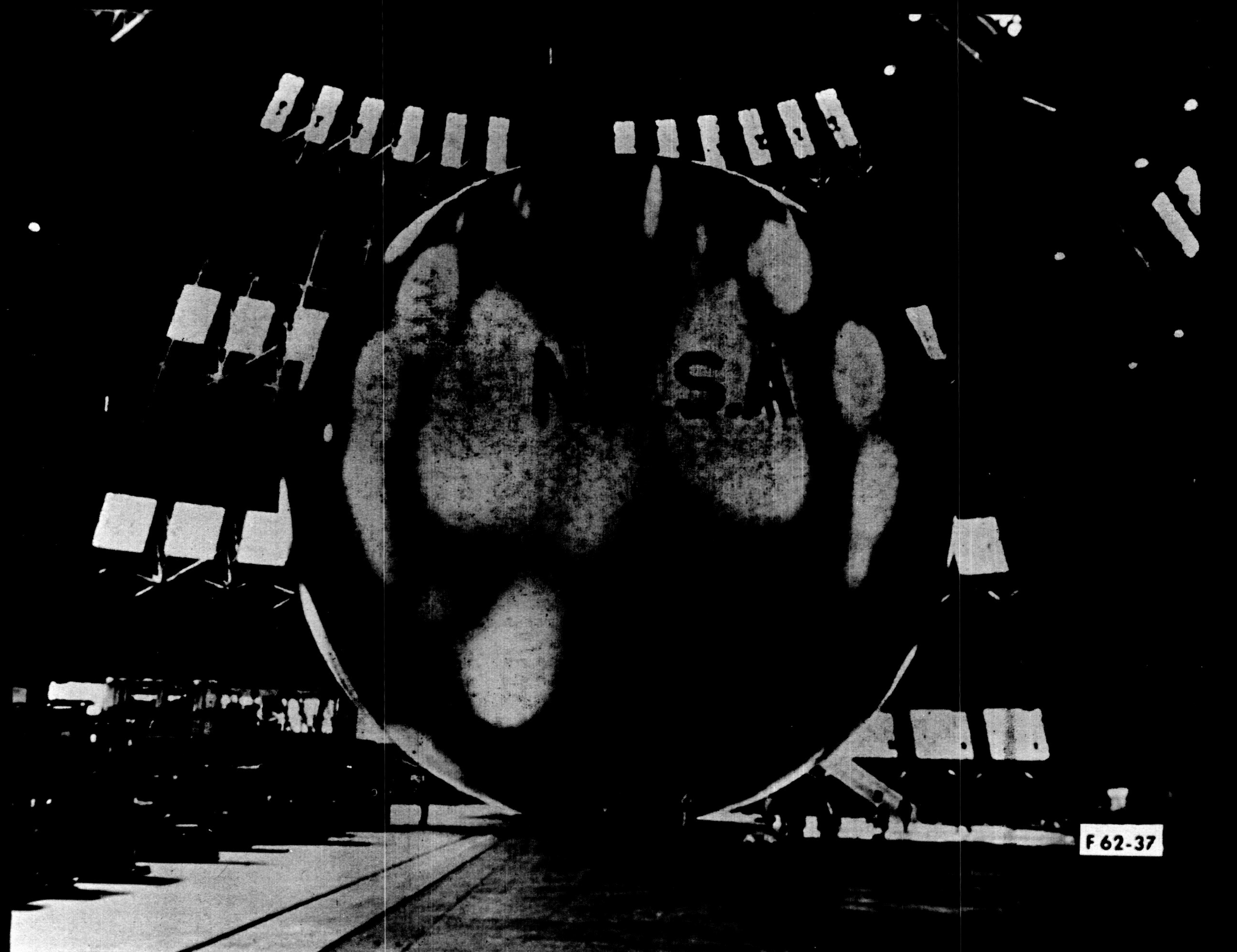

ACTIVE COMMUNICATIONS SATELLITES
SYNCHRONOUS ORBIT
F62-33

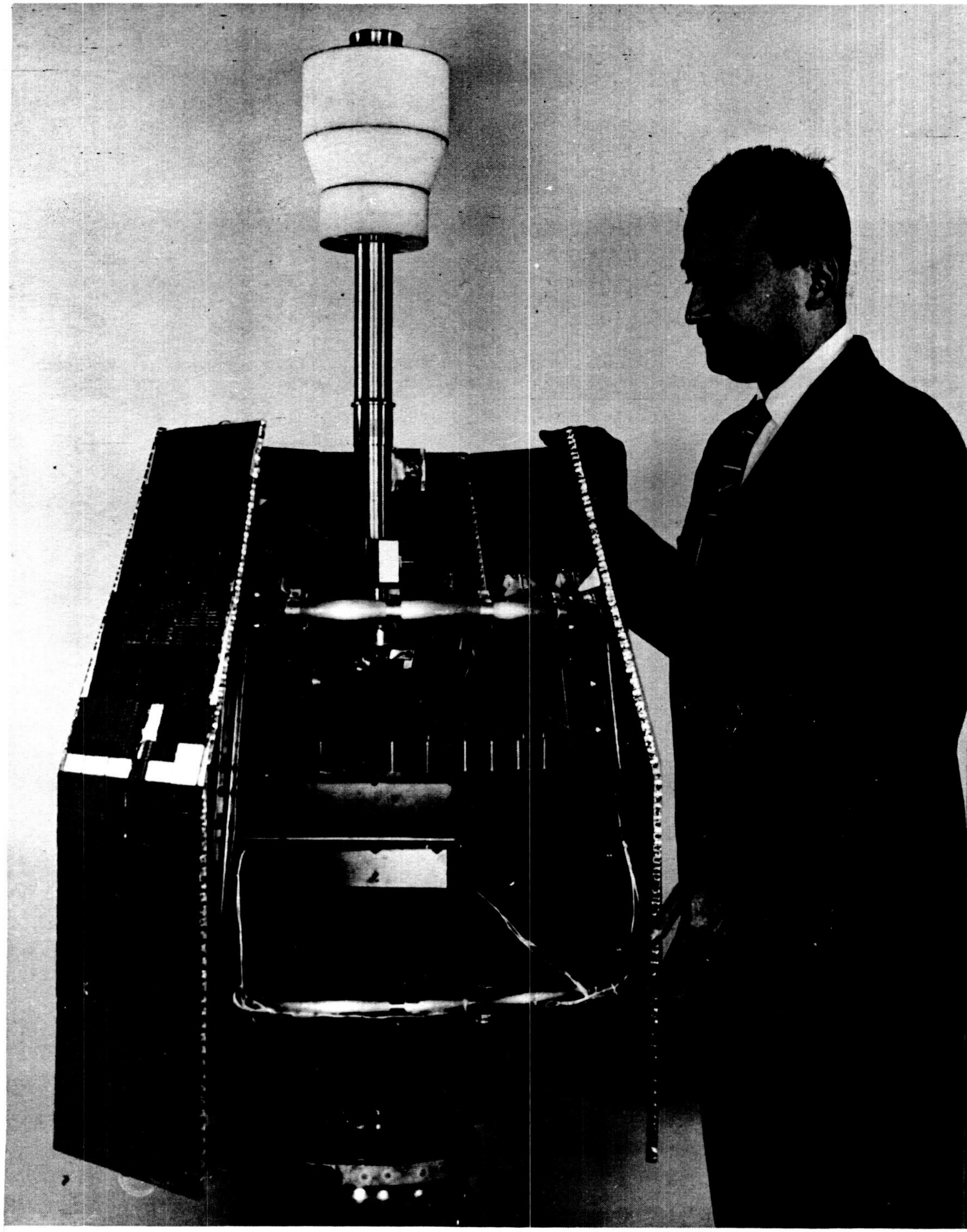

MULTI-LAUNCH CONCEPT
1
2
1
3
2
1
F62-34


FORMS OF PASSIVE
COMMUNICATION SATELLITES
SPHERE
SPHERE WITH
ETCHED HOLES
MESH
SPHERE
SPHERICAL
SEGMENT
GRAVITY
STABILIZED
F 62-35


ECHO I
CONSTRUCTION....
0.0005 INCH
ALUMINIZED MYLAR
DIAMETER 100 FT.
WEIGHT 135 LBS.
ECHO II
CONSTRUCTION....LAMINATE OF
0.0002 INCH ALUMINUM
0.00035 INCH MYLAR
0.0002 INCH ALUMINUM
DIAMETER 135 FT.
WEIGHT 500 LBS.
F 62-36

ECHO II

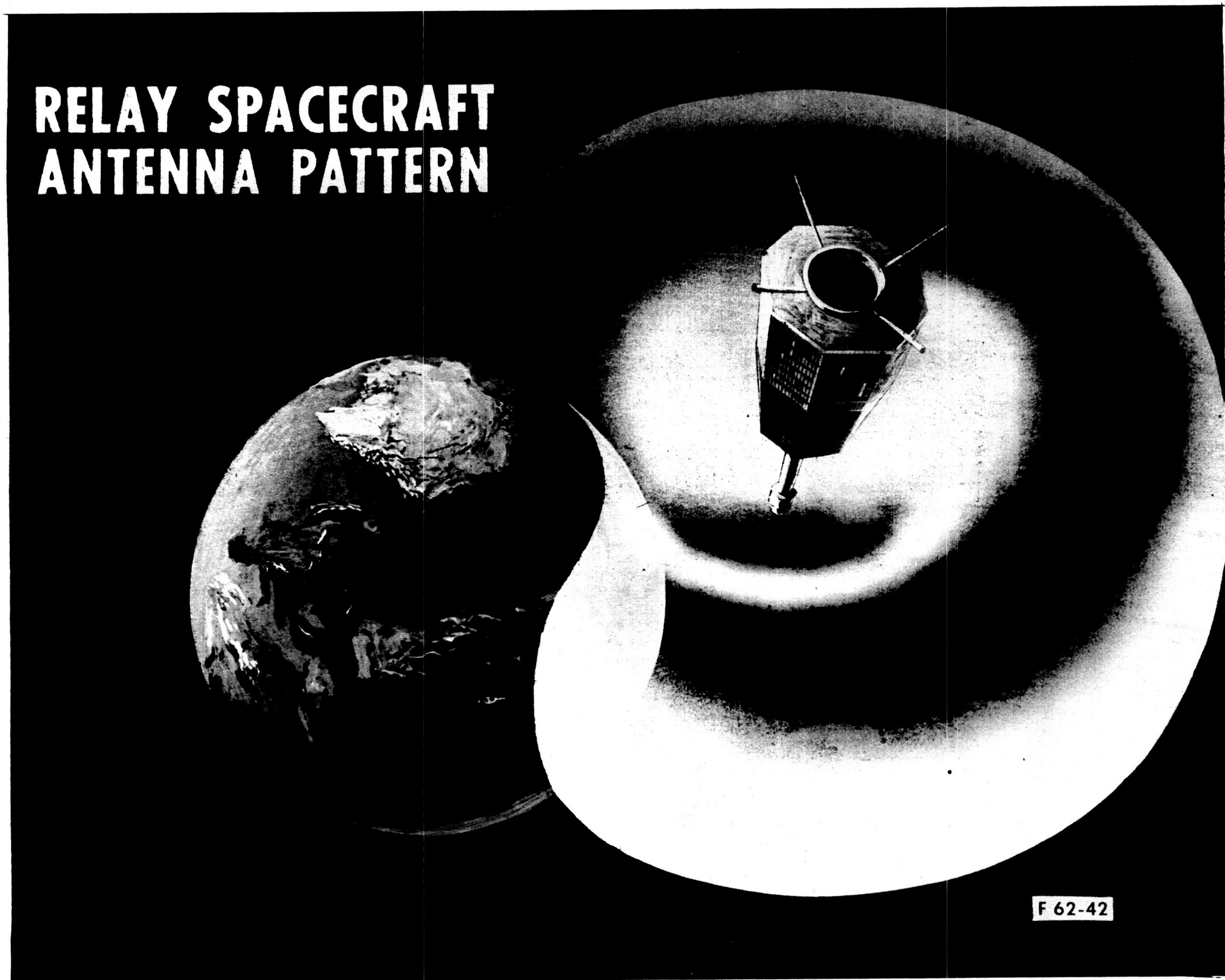




RELAY
SPACECRAFT

F 62-41

21


RELAY SPACECRAFT
ANTENNA PATTERN
F 62-42

TELSTAR SPACECRAFT

23

NASA AND AT&T RESPONSIBILITIES FOR TELSTAR

NASA

- ESTABLISHMENT OF ENVIRONMENTAL TEST SPECIFICATIONS FOR THE SPACECRAFT
- LAUNCH VEHICLE PROCUREMENT AND SPACECRAFT LAUNCH
- ORBITAL DATA ACQUISITION

AT&T

- SPACECRAFT DEVELOPMENT

  GROUND STATION DEVELOPMENT

NASA & AT&T

- DATA ANALYSIS AND PROCESSING TO SUPPORT RESEARCH AND DEVELOPMENT ON SPACECRAFT AND GROUND SYSTEMS

F 62-45

FUTURE APPLICATIONS

- OTHER SATELLITE APPLICATIONS
- INDUSTRIAL APPLICATIONS

F 62-48

INDUSTRIAL APPLICATIONS

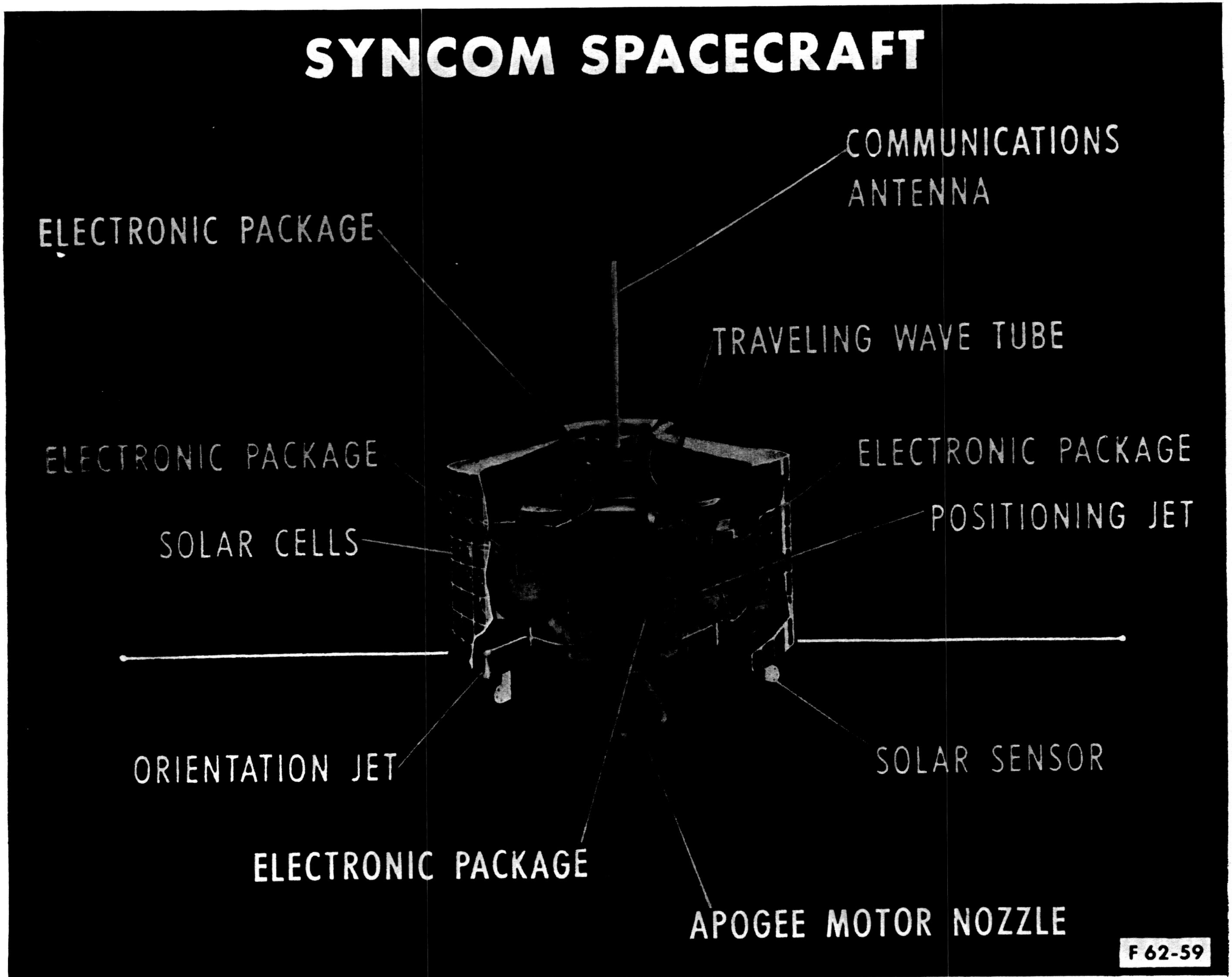
- RECOGNIZE THE PROCESS, MATERIAL, OR DEVICE
- CATALOG THE USEFUL PROPERTIES
- INFORM POTENTIAL USERS
- EVALUATE AND REFINE THE PROCEDURES FOR PROCESSING APPLICATIONS INFORMATION

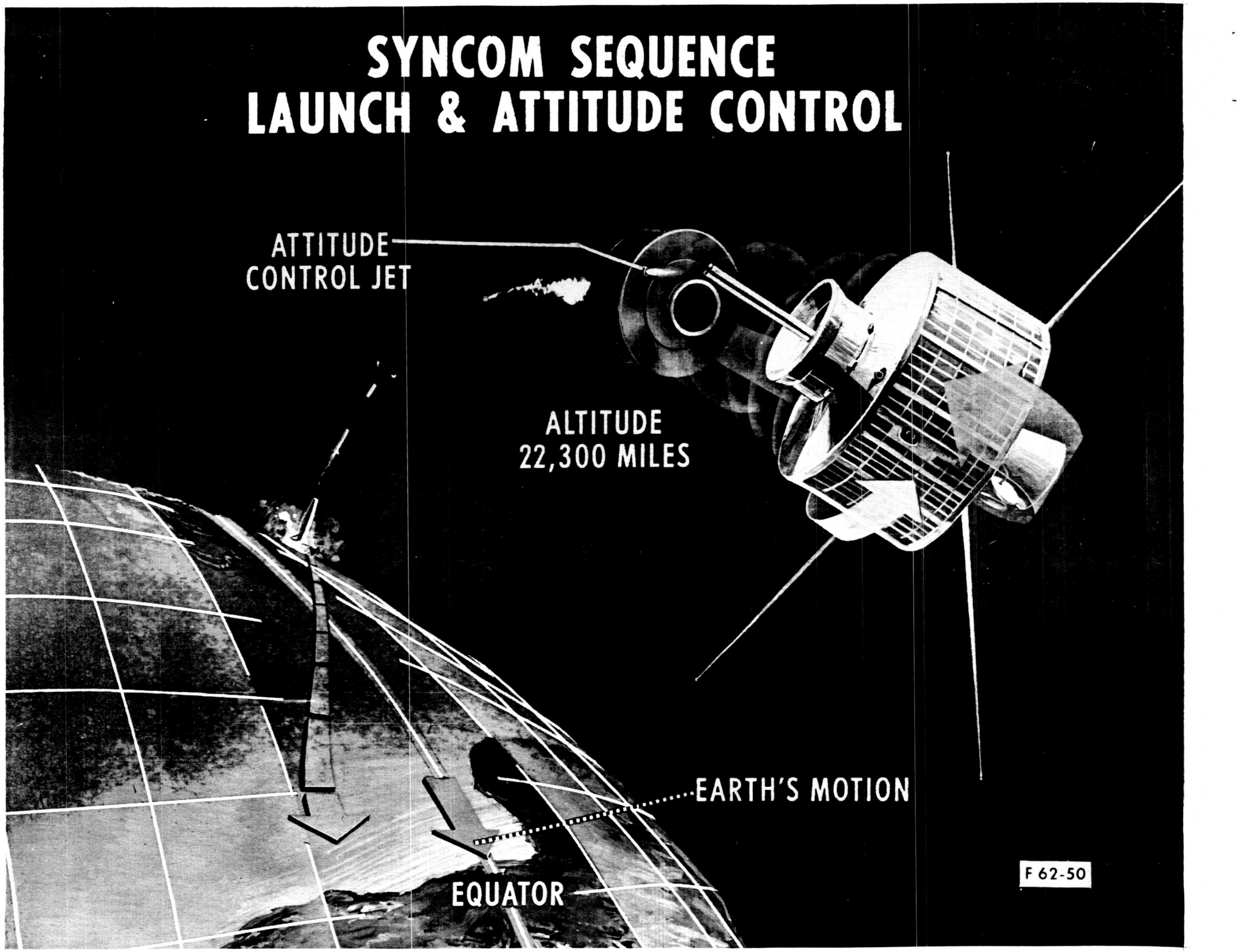
F62-58

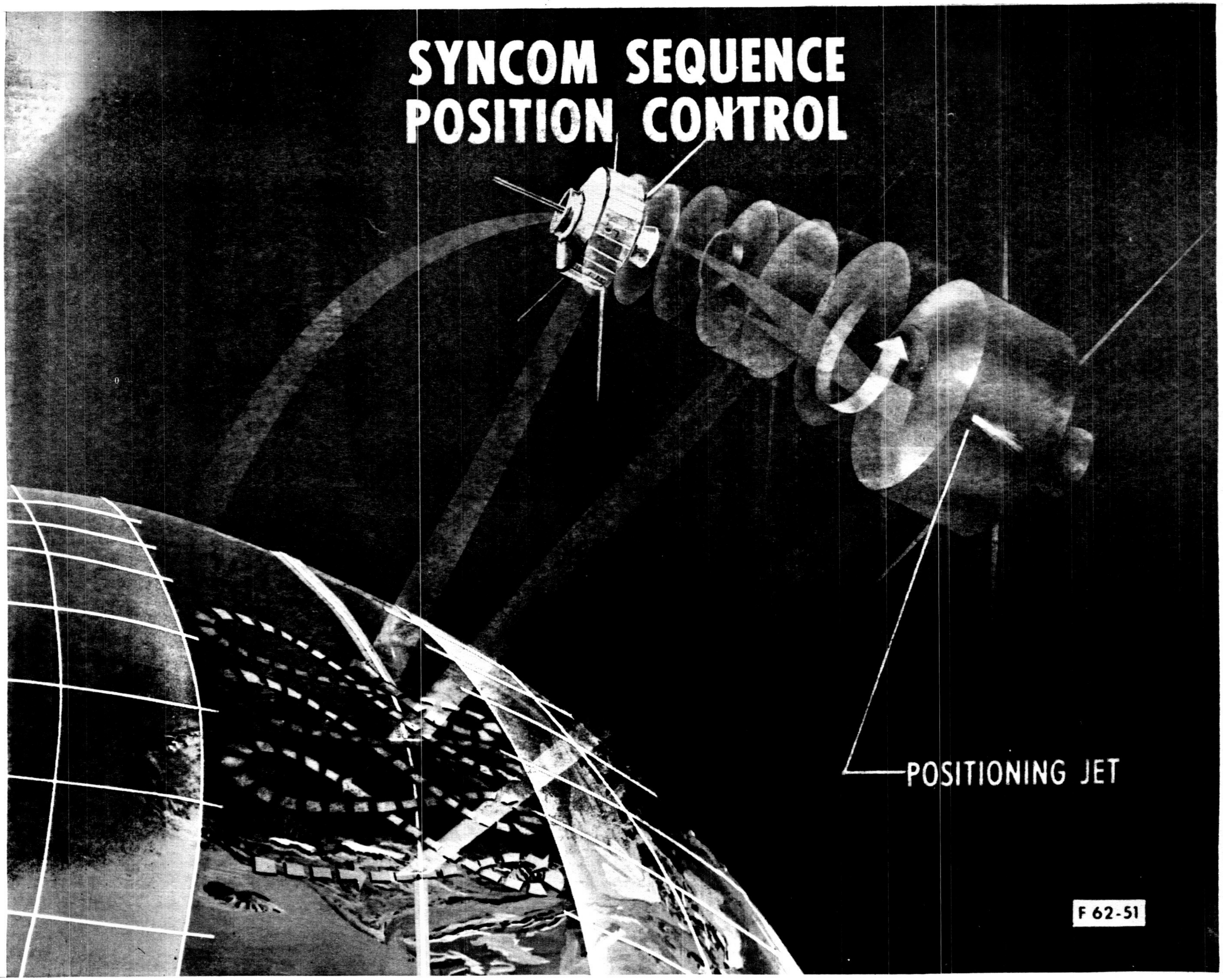
SYNCOM OBJECTIVES

- PROVIDE EXPERIENCE IN SYNCHRONOUS ORBIT AT EARLIEST TIME
- DEVELOP CAPABILITY FOR LAUNCHING INTO 24-HOUR ORBIT WITH "APOGEE KICK" TECHNIQUE
- TEST COMPONENTS LIFE AT 24-HOUR ORBIT ALTITUDE

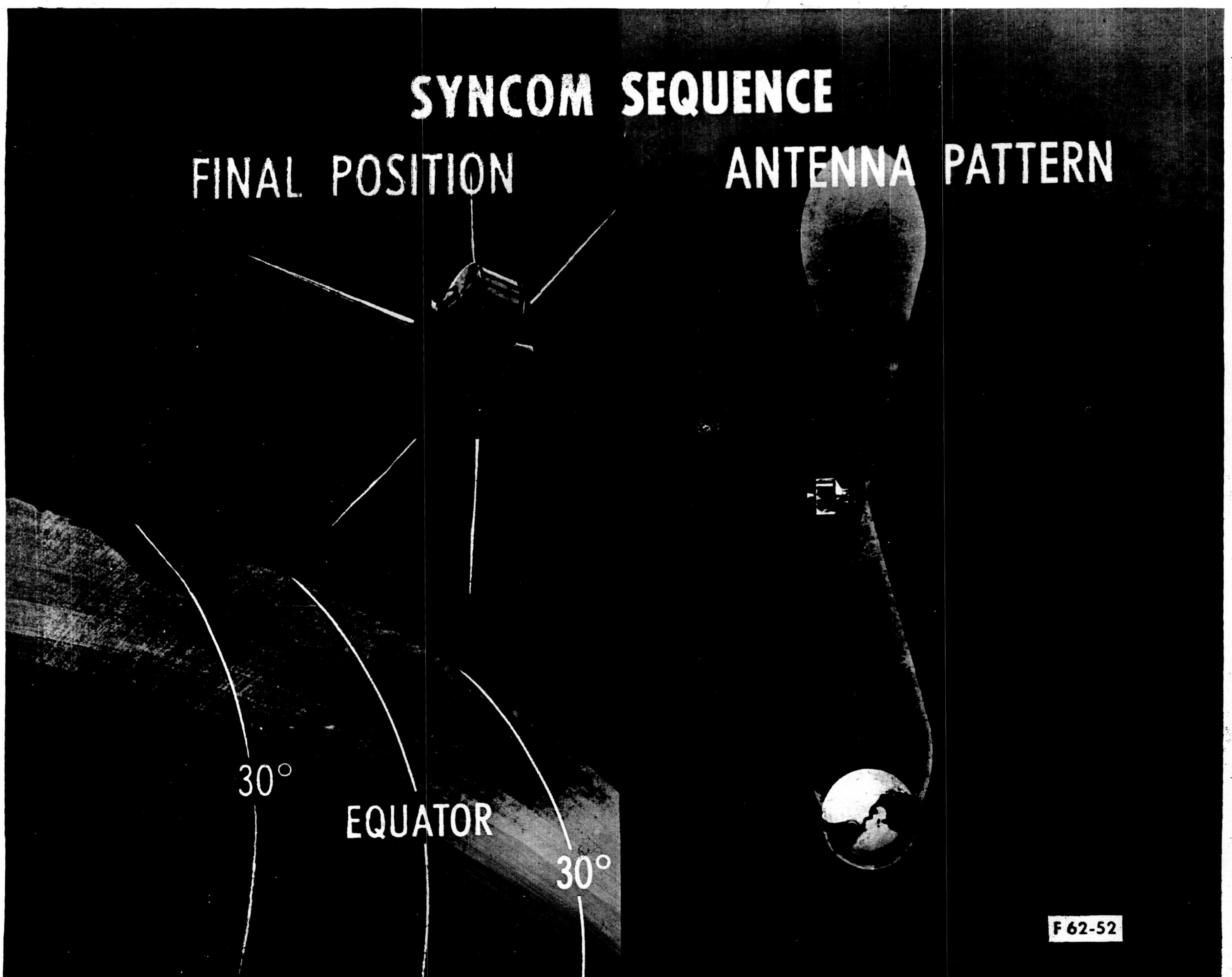
F 62-67


SYNCOM SPACECRAFT
COMMUNICATIONS ANTENNA
ELECTRONIC PACKAGE
TRAVELING WAVE TUBE
ELECTRONIC PACKAGE
ELECTRONIC PACKAGE
POSITIONING JET
SOLAR CELLS
ORIENTATION JET
SOLAR SENSOR
ELECTRONIC PACKAGE
APOGEE MOTOR NOZZLE
F 62-59


SYNCOM SEQUENCE
LAUNCH & ATTITUDE CONTROL
ATTITUDE
CONTROL JET
ALTITUDE
22,300 MILES
EARTH'S MOTION
EQUATOR
F 62-50



26


SYNCOM SEQUENCE
FINAL POSITION
ANTENNA PATTERN
30°
EQUATOR
30°
F 62-52

NASA AND DOD RESPONSIBILITIES FOR SYNCOM

NASA	•	SPACECRAFT DEVELOPMENT AND LAUNCH
	•	ORBITAL DATA ACQUISITION AND PROCESSING
DOD	•	GROUND STATION DEVELOPMENT
NASA & DOD	•	DATA ANALYSIS AND PROCESSING TO SUPPORT RESEARCH AND DEVELOPMENT ON SPACECRAFT AND GROUND SYSTEMS

F62-53

ADVANCED RESEARCH AND DEVELOPMENT-
COMMUNICATIONS SYSTEMS

PROGRAM ELEMENTS

- GROUND SYSTEMS COMPONENTS
- SATELLITE SYSTEMS COMPONENTS
- ATTITUDE STABILIZATION
- ENVIRONMENTAL RADIATION EVALUATION

F 62-54

ACTIVE COMMUNICATIONS SATELLITES SYSTEMS IMPROVEMENT

LOW ALTITUDE SYSTEMS		SYNCHRONOUS SYSTEMS	
RELAY	ADVANCED	SYNCOM	ADVANCED
DELTA VEHICLE	ATLAS-AGENA B VEHICLE	DELTA VEHICLE	ATLAS-AGENA B VEHICLE
150 LBS.	600 LBS.	55 LBS.	500 LBS.
700 TO 3,000 MI. ELLIPTICAL ORBIT	UP TO 12,000 MI. CIRCULAR ORBIT	22,300 MI. INCLINED ORBIT	22,300 MI. EQUATORIAL ORBIT

F 62-55

ACTIVE COMMUNICATIONS SATELLITES
SYSTEMS IMPROVEMENT

LOW ALTITUDE SYSTEMS		SYNCHRONOUS SYSTEMS	
RELAY	ADVANCED	SYNCOM	ADVANCED
1 TV CHANNEL	4 TV CHANNELS	1 TELEPHONE CHANNEL	4 TV CHANNELS
SPIN STABILIZED	EARTH ORIENTED	INCLINED ORBIT	EQUATORIAL ORBIT
AVAILABLE 10% OF THE TIME	AVAILABLE 25% OF THE TIME	AVAILABLE 75% OF THE TIME	AVAILABLE 100% OF THE TIME
2-STATION SYSTEM	MANY-STATION SYSTEM	2-STATION SYSTEM	MANY-STATION SYSTEM

F62-56